DEVELOPING A NOISE AND SOUNDSCAPE CONCEPTUAL FRAMEWORK FOR FAIR AND EQUITABLE DISTRIBUTION OF AIRCRAFT

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1 INTRODUCTION

This paper presents an overview of the findings and outcomes of an independent study carried out between September 2021 and March 2022, based on the work of the authors[1], to develop a conceptual framework to define and assess options for the Fair and Equitable Distribution (FED) of aircraft at Gatwick Airport, UK[1]. The airport's FED of traffic would help enable airspace managers and aircraft operators to design solutions to meet the proposed FED objective in the context of the UK's Airspace Modernisation Strategy (AMS)[2]. A transdisciplinary soundscape conceptual framework (see Figure 1) for operationalising the development of an agreed definition of FED is presented, for the first time, to the best of the authors' knowledge. The resulting framework incorporates acoustics, psychoacoustics, non-acoustic factors, air traffic management technology options, health, psychology and other contextually specific community and stakeholder engagement disciplines. It is proposed that the FED framework can be applied to other airports when adapted for locally significant contextual factors. The learnings from the transdisciplinary soundscape approach also have implications for, and are generally applicable to, noise management across all transportation modes to reduce annoyance and improve health and wellbeing.

2 FAIR AND EQUITABLE DISTRIBUTION OF AIRCRAFT AT GATWICK AIRPORT

2.1 Background

Fair and Equitable Distribution (FED) was introduced in 2015 as an aspirational objective among others, by communities affected by noise from aircraft using London's Gatwick Airport. Gatwick Airport's Noise Management Board (NMB) considered during its 1st term (2016-2019)[3] how FED could be achieved. This independent study was tasked, as part of a range of ongoing activities by the airport, with studying aspects of the workable implementation of FED.

2.2 Airspace Modernisation Strategy and Gatwick Airport

The AMS sets out a shared objective between the Civil Aviation Authority (CAA) and the Department for Transport (DfT) for modernising airspace which is to deliver quicker, quieter and cleaner journeys and more capacity for the benefit of those who use and are affected by UK airspace. The Future Airspace Strategy Implementation – South (FASI-S)[2] proposals are part of a UK wide airspace upgrade programme, which in turn are part of a global programme of airspace modernisation arising as a result of the introduction of satellite navigation technology and other advances in aviation. From an airspace design perspective, in addition to the physical characteristics and limits of aircraft and airport operation, which are provided for in regulation and policy, the harmful effects of aircraft noise should be considered when making changes to airspace and procedures, *these may include health and wellbeing impacts as well as non-acoustic factors*. For the purpose of assessing airspace changes, according to the Air Navigation Guidance[4], the UK government wishes the CAA to interpret this objective to mean that the total adverse effects on people as a result of aviation noise should be limited and, where possible, reduced rather than the absolute number of people in any particular noise

contour. The CAA and DfT acknowledge that while it may not be possible to completely reduce the impact of aviation noise for all communities at all times, it is important that noise is managed as well as possible and the adverse impacts minimised in accordance with the best available evidence, technology and means. Adverse effects are considered to be those related to health and quality of life. Airports should also consider whether they can develop airspace change proposals to reduce noise, i.e*., to reduce the total adverse health and wellbeing and non-acoustic factors effects of noise while improving the quality of local sound environments.*

3 SCOPE

3.1 Scope, Aims and Objectives

Based on the requirement of the AMS, on behalf of the Gatwick Airport NMB, Gatwick Airport Limited commissioned a team led by the University of Salford, with St George's, University of London and the UK Noise Abatement Society, to: *Deliver an independent study to inform NMB stakeholder discussions as a part of a process established by the NMB Workplan, during the development of potential Gatwick FASI-S proposals, part of a UK wide Airspace Modernisation Strategy, for consideration during development of design options, in which the definition and quantification of FED of aircraft should be a factor – in line with the NMB's Mission.* The study included feedback and contributions from a range of stakeholders including: community noise groups, local authority and elected council representatives, National Air Traffic Services[5], Air Navigation Solutions[6], the CAA, the DfT, aviation industry stakeholders and Gatwick Airport. The study included a review of UK policies and regulations, as well as best practice and viable technology options, a review of the health effects of aviation noise, non-acoustic factors; and the views of communities expressed to Gatwick, through meetings of its NMB, and in a workshop convened for this purpose. The objectives of the study are shown in Table 1.

Table 1. The objectives of the independent study[1,Table 1-1], led by the University of Salford, with St George's, University of London and the Noise Abatement Society, to inform Gatwick Airport's Future Airspace Strategy Implementation – South (FASI-S) proposals.

Objective	Description
1	Describe current regulations, policy and guidance for the mitigation of aircraft noise in relation to airspace design.
2	Take into account expected policy and regulation developments.
3	Note any gaps observed in the policy, regulatory and process frameworks relevant to airspace design and change.
4	Identify available and expected future technical and procedural options for the fair and equitable distribution of arriving and departing aircraft.
5	Develop potential methodologies, suitable for use in the CAP1616[7] process, for evaluating the effectiveness of each of the identified traffic distribution options to deliver fair and equitable distribution of aircraft.
6	Engage through workshop(s) with all NMB stakeholders on the points above.

4 RECOMMENDATIONS

4.1 Policy, Regulations, Design and Guidance

Objective 1 – regarding policy and regulations, the study recommends two key aspects should be considered for the inclusion of FED objectives in the development of Gatwick's FASI-S airspace change proposals: (i) Environmental noise is a priority below 4,000 feet, where the objective is to limit and, where possible, reduce the total adverse effects on people; (ii) Department for Transport's Web-

based Transport Analysis Guidance (WebTAG)[8] as the tool for assessing airspace change proposals should be updated. N.B. a dialogue would need to be opened with the CAA to discuss how WebTAG+ and/or health dashboard and NAFs analyses could additionally be taken into account in their decision making.

Objectives 2 and 4 - regarding design and guidance, the study describes the noise related requirements to be addressed by airspace modernisation and summarises a number of airspace design concepts with the potential to offer noise mitigation that are drawn from UK CAA Guidance CAP1378[9], introduces Performance Based Navigation (PBN) technologies, and summarises how they can be used to either concentrate or accurately disperse traffic with the aim of reducing aircraft noise exposure. Also described are several airspace design concepts that offer the potential to provide noise mitigation of both departure and arrival operations. The findings of CAP1378 regarding the minimum lateral distance between routes to ensure meaningful changes in aircraft noise exposure on the ground are also summarised.

4.2 Noise Metrics and Technology Options

Objective 5 – regarding a review of the most commonly studied aviation noise metrics[10] it was noted that although time averaged metrics, such as $L_{Aeq,T}$ are widely studied, relatively simple to understand and are somewhat correlated to annoyance, other metrics such as Number Above (NA), L_{Amax} and Intermittency Ratio[11] can provide more information about the number of overflights effectively contributing to the total aircraft noise exposure. It was recommended that other acoustic and psychoacoustic metrics[12] to better account for short-term noise exposure and impacts with respite, relief or dispersal schemes needed further investigation. Reviewing the acoustic metrics was recommended as part of a fundamental framework needed to address the objective effects of aircraft noise on health and the assessment of non-acoustic factors, as summarised in Table 2.

Table 2. Brief summary of the basic acoustic metrics used for the assessment of aviation noise impact and recommendations[1,Table 4-1].

Requested by CAA	• $L_{Aeq,16h}$ (daytime), $L_{Aeq,8h}$ (night-time), • N65 (daytime), N60 (night-time)
Monitored by Gatwick Airport	• $L_{Aeq,T}$: ○ $L_{Aeq,16h}$ (daytime), $L_{Aeq,8h}$ (night-time) • NA Metrics: ○ N60 (daytime) at 20, 50, 100, 200, 500 events ○ N60 (night-time) at 10, 20, 50 and 100 events
Recommended to be used in addition by this study	$L_{Aeq,T}$ (with integration time T able to account for short-term changes in noise exposure due to relief/respite schemes), Intermittency Ratio, L_{Amax}, other psychoacoustic metrics (such as Loudness)

4.3 Evidence Base for the Effects of Aviation Noise on Health

Objectives 2, 3 and 5 – regarding an overview of the current evidence base for the effects of aviation noise on health, these recommendations identified up-to-date evidence for outcomes considered in WebTAG[8], as well as identifying evidence for health outcomes not currently considered in WebTAG. Also considered were health metrics to measure and report noise impacts, as well as consideration of the evidence for health effects associated with change in aircraft noise exposure. The recommendations from the overview of the evidence base for the effects of aviation noise on health and consideration of health as a metric for FED are shown in Table 3.

Table 3. Overview of the evidence base for the effects of aviation noise on health and consideration of health as a metric for FED of aircraft at Gatwick Airport[1,p.97].

1	Increasing acceptance of, and evidence that aviation noise affects a range of health outcomes including annoyance; sleep disturbance; cardiometabolic disease; mental health, wellbeing, quality of life; and children's learning;
2	The role of health in the Noise Policy Statement for England[13] in terms of avoiding, mitigating and minimising adverse impacts on health and quality of life and the use of LOAEL (lowest observed adverse effect level) and SOAEL (significant observed adverse effect level) values for assessments;
3	The health evidence base underlying the DfT's (WebTAG); The potential to assess health effects of aviation noise beyond the WebTAG methodology to inform FED;
4	Recent exposure-response functions for annoyance; sleep disturbance; cardiometabolic disease; children's learning; mental health, wellbeing and quality of life;
5	The World Health Organization (WHO) Guidelines[14] for aviation noise;
6	Uncertainty in the evidence-base for annoyance including differences between the WHO exposure-response function and the Survey of Noise Attitudes (SoNA) 2014[15] exposure-response function;
7	The reliance on steady-state relationships in noise and health impact assessments and lack of studies of airspace change, change in exposure, and respite;
8	The lack of studies of event-related metrics, such as Number Above (NA) or other metrics such as the Intermittency Ratio and overflights;
9	The lack of UK-based studies of sleep disturbance and lack of evidence relating to differential effects on vulnerable groups in the population for most health outcomes;
10	The potential to update the exposure-response functions used and to add additional health outcomes to WebTAG, which would need to be discussed and agreed with the CAA;
11	The need for assessments to account for uncertainty in the evidence base by assessing different exposure-response functions for the same health outcome (e.g., WHO and SoNA 2014 for annoyance);
12	Limitations in ability to quantify the effects of a change in aircraft noise on health;
13	Uncertainty in the use of WebTAG at small geographical scales and in terms of how health impacts influence the CAA's decision making in the airspace change process.

4.4 Non-acoustic Factors

Objectives 2, 5 and 6 – regarding an overview of the role of non-acoustic factors (NAFs) in the context of the human response to sound in general[16,17] and aviation noise in particular[18,19], the recommendations described the importance of NAFs as significant to consider when evaluating the effectiveness of different options to deliver FED of aircraft. The role of the ISO Soundscape Standards[20-22] in assessing NAFs, NAFs in noise and planning policy, and the view of the International Civil Aviation Organization (ICAO)[23] regarding NAFs were discussed. A conceptual framework to aid with the development of a FED consultation process with all stakeholders and, in particular, communities was recommended to assist in the development of an effective definition of FED *in context* (see Figure 1). The following key points were discussed/recommended:

- General concepts in the literature regarding NAFs and their application to support the development of an effective definition of FED in the context of aviation noise;
- A definition of NAFs to be used to support the development of an effective definition of FED in the context of aviation noise, as: "All those factors other than noise level alone which contribute to annoyance."[24,p.1];
- An illustrative integration of NAFs, ISO Soundscape Standards, acoustics, psychoacoustics, noise and health to support the development of an effective definition of FED;
- The integration of NAFs in policy, building on the health and wellbeing policies discussed;

- The identification by ICAO of the importance of NAFs, in relation to community aircraft noise annoyance, to be considered in aviation policy;
- The proposal that assessment of NAFs can contribute to the evaluation of FED, in addition to the CAP1616 requirement to use WebTAG for airspace redesign and recommends the addition of specific NAF outcomes via a WebTAG+ approach building on, for example, the Amenity metric.

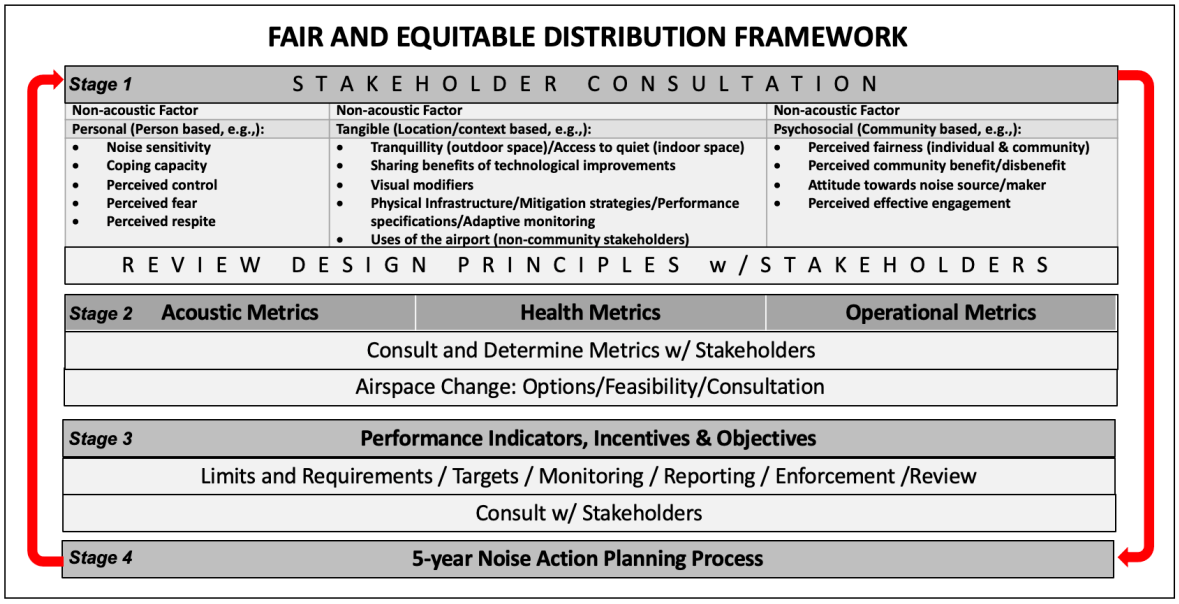

Figure 1. Conceptual framework[1,Figure 7-1] of the general stages recommended for operationalising the development of an agreed definition of Fair and Equitable Distribution of aircraft, adapted from[25-28]. It is recommended that the assessment of non-acoustic factors is conducted either within a standardised soundscape process and/or within a framework of a good acoustic design process. In addition, when applying the framework, *situational* factors[e.g.18,29,30] should also be included in the assessment of salient non-acoustic factors. ©Lavia, Clark and Torija.

4.5 Community Feedback

Objective 6 - regarding supporting the work carried out in this study, a workshop with all NMB stakeholders was organised on the 7th of December 2021. During this workshop community representatives were invited to provide any views or objectives regarding: the concentration versus dispersal of aircraft (and thus aircraft noise); metrics to assess aircraft distribution and their use in assessing FED of aircraft; the health effects of aircraft noise and their relevance in assessing FED; and non-acoustic metrics that could additionally support FED in relation to aircraft. A summary of views from affected communities were considered by the delivery team and reflected in the recommendations presented to Gatwick Airport (see Table 4).

5 CONCLUSIONS

This paper presents an overview of the findings and outcomes of an independent study[1] led by University of Salford, with St George's University of London and the UK Noise Abatement Society, carried out between September 2021 and March 2022. The aim of the project was to: *Deliver an independent study to inform NMB stakeholder discussions as a part of a process established by the NMB Workplan, during the development of potential Gatwick FASI-S proposals, part of a UK wide Airspace Modernisation Strategy, for consideration during development of design options, in which the definition and quantification of FED of aircraft should be a factor, in line with the NMB's Mission.*

The study provides a range of recommendations encompassed in the three main areas of the findings: ***(i)* Aviation Noise Metrics and Technology Options**; ***(ii)* Health Effects of Aircraft Noise;** and ***(iii)* Non-acoustic Factors and FED**. The recommendations are summarised in Table 4.

Table 4. Recommendations of the independent study to develop an effective definition of Fair and Equitable Distribution (FED) of aircraft at Gatwick Airport[1,Table 7-1].

Recommendations	
Aviation Noise Metrics and Technology Options	
1	This study recommends a conceptual framework (Figure 1), taking account of acoustic, psychoacoustic, non-acoustic and health factors to: *(i) aid the development of a FED consultation (or co-creation) process with the affected and wider communities around Gatwick Airport; and (ii) the development of an agreed definition of FED.*
2	This study recommends further work to understand the capabilities of available acoustic and psychoacoustic metrics, and to assess whether they are better able to account for short-term noise exposure and impacts with respite, relief or dispersal schemes, than $L_{Aeq,16h}$. For example, this could include (*i) the use of complementary metrics such as NA, L_{Amax}, Intermittency Ratio; and (ii) an 'optimal dispersal' of traffic where the harmful impacts of aircraft noise are reduced, while reducing the total number of people exposed to significant aircraft noise*
3	This study recommends further work to better understand the benefits of noise respite around Gatwick Airport, and also options to improve an effective delivery of noise respite.
4	This study recommends carrying out an in-depth investigation of the human response to noise exposure for newly overflown.
Health Effects of Aircraft Noise	
5	This study proposes that health outcomes can contribute to the evaluation of FED, in addition to the CAP1616 requirement to use WebTAG for airspace redesign. A health dashboard could be agreed between stakeholders, which could report the health impacts of key noise metrics for areas around Gatwick Airport.
6	This study recommends that where health effects are assessed, sensitivity analyses are undertaken on the assessments where there is uncertainty in the evidence, using a number of exposure-response functions.
7	This study recommends that the health effects are assessed across a wide-range of exposures, including populations exposed to lower levels, for example, <50 dB $L_{Aeq,16h}$.
8	This study recommends the expansion of the health outcomes included in WebTAG, via a WebTAG+ approach.
Non-acoustic Factors and FED	
9	This study proposes assessing NAFs as part of the process for airspace redesign during the CAP1616 consultation stages[7,pp.34-60] to inform: *(i) Stage 1, Step 1B, Design principles; (ii) Stage 2, Develop and Assess; (iii) Stage 3, Consult; and Stage 4, Update and Submit.*
10	This study proposes that assessment of NAFs can contribute to the evaluation of FED, in addition to the CAP1616 requirement to use WebTAG for airspace redesign. This study recommends the addition of selected NAF outcomes via a WebTAG+ approach building on, for example, the Amenity metric.
11	This study recommends a stakeholder consultation to assess the NAFs and soundscape requirements/preferences of those affected by Gatwick Airport operations and the airspace change process (ACP).
12	This study recommends that the outcomes of **Recommendation 11** be used to review the ACP design principles with stakeholders and inform the development of an agreed definition of FED.
13	This study recommends that the outcome of **Recommendation 12** be used to develop a methodological framework to operationalise FED with the following metrics and processes*: (i) agreed acoustic, psychoacoustic, health and operational metrics; (ii) agreed performance*

	indicators, incentives and objectives; and (iii) the integration of the agreed metrics into Gatwick Airport's 5-year Noise Action Planning[31] process.
14	This study recommends that **Recommendations 11, 12 and 13** be systematically reviewed with stakeholders as part of Gatwick Airport's 5-year Noise Action Planning[31] process and a *standardised continuous improvement programme* to reduce the adverse impacts from noise and increase the beneficial impacts of good quality sound environments (experienced in relation to the airport and ACP process) be agreed with stakeholders.

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