Working towards more socially acceptable outcomes from airspace modernisation

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ABSTRACT

The UK is currently undertaking a process of airspace modernisation, which has revealed potentially competing objectives for the management of aircraft noise impacts. Communities at some airports are concerned about the fairness of potential outcomes in terms of changes to the pattern of aircraft noise exposure.

This research draws upon in-depth community focus groups where the fairness and equity of different airspace change concepts for a fictitious departure route were discussed using a virtual airport scenario. These discussions revealed a preference of minimal change compared to the existing patterns of noise exposure, where the use of a number above metric (N65) was particularly helpful in allowing participants to understand the implications of different airspace change options on the spatial distribution of noise on the ground.

The paper demonstrates how N65 data can be used to summarise the consequences of different airspace change options, supporting stakeholders in assessing the relative distributional fairness of each proposal. Such transparency around the consequences of airspace change proposals enhances informational fairness and can help build trust in the procedural fairness of airspace decision-making leading to more socially acceptable outcomes (or the least socially unacceptable outcomes).

1. INTRODUCTION

The UK has embarked on a radical process of Airspace Modernisation to optimise the benefits from the adoption of performance-based navigation (PBN) that has been gradually

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introduced across most airline fleets as newer planes incorporating this technological capability have been purchased. PBN has increasingly been replacing ground-based navigation systems with on-board systems incorporating satellite navigational aids with the result that aircraft are able to fly prescribed routes with increased predictability and accuracy. A key benefit of this feature of PBN according to the UK Government[1] is that it concentrates traffic and thus increases airspace capacity thereby 'unlocking' growth, improving safety and offering environmental gains through more direct routing. At the same time, the Department for Transport issued Air Navigation Guidance[2] to the UK Civil Aviation Authority (UK CAA – the body responsible for overseeing airspace changes in the UK), which acknowledged the potential negative environmental impact of changes and highlighted objectives supporting 'a strong and sustainable aviation sector' (p.8). These are to:

- Limit and, where possible, reduce the number of people in the UK significantly affected by adverse impacts from aircraft noise
- Ensure that the aviation sector makes a significant and cost-effective contribution towards reducing global emissions; and minimise local air quality emissions and in particular ensure that the UK complies with its international obligations on air quality.'

Thus, from a noise perspective, the UK CAA and airports responsible for coming forward with airspace change proposals were charged with balancing economic and social benefits from a growing air transport system and any associated emissions outcomes with the potential adverse noise impacts on communities near airports. Given the complexity of the potentially competing objectives and indeed aspects of noise management, the guidance states that **all changes below 7000 feet should take into account local circumstances** and not be agreed by the CAA before **appropriate community engagement has been conducted by the sponsor.** To this end the UK CAA published in 2017, and has since revised on five occasions, *CAP 1616 Airspace Change*[3] in which the regulatory process for changing airspace is outlined. This establishes a 7-stage procedure that airspace change sponsors must complete including specific requirements for stakeholder engagement and UK CAA approval at pre-determined gateway points in the decision-making process (Figure 1).

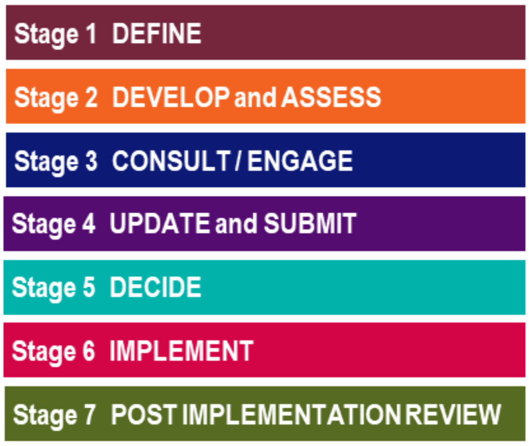

Figure 1: CAP1616 Prescribed process for airspace change

In earlier work undertaken as part of EU H2020 Project ANIMA[4], Stage 1 efforts to engage with local communities in defining 'Design Principles' were critically reviewed. This revealed that considerable efforts were made by the larger UK airports to consult with a wide range of stakeholders through various channels and utilising a range of different techniques. These enabled airports to identify key design principles that should guide the later development of specific airspace change proposals. These principles covered the following groups of issues:

- Safety

- Airspace users
- Technology
- Policy
- Capacity
- Emissions
- Noise

Despite apparent clarity on these design principles (DPs) two key omissions looked set to reduce the value of this consultation stage on subsequent stages in the UK CAA process of airspace change development and implementation. First, there was a general lack of ranking/prioritising design principles which, it was concluded, would likely make the process of trading-off between principles very challenging, particularly where DPs appear to be conflicting such as the preference for dispersing tracks, whilst attempting to minimise the number of people overflown. Second, there appeared to be very little discussion, let alone agreement on how to capture performance against specific noise-related DPs using metrics that describe operations and their noise consequences (to allow the relative merits of different airspace change options to be illustrated and informed decisions made). Again, this conclusion indicated the subsequent appraisal and consultation around specific airspace change proposals would be all the more problematic.

The research reported here seeks to address these two omissions by engaging directly with noise affected communities around one UK airport to better understand perceptions of the (un)fairness of different patterns of the lateral distribution of aircraft resulting from airspace change concepts. Specifically, it sought to develop metrics to capture critical features of changes to the noise environment which appear to influence perceptions of (un)fairness and thus the risk of socially unacceptable outcomes from the airspace modernisation process.

2. EXPLORING DISTRIBUTIONAL (UN)FAIRNESS

In their paper linking concepts of social justice to aircraft noise exposure Hauptvogel et al[4] explain that perceptions of distributional fairness are influenced by the balance between the costs and the benefits of a change (Figure 2). However, the perception of the relative merits of costs and benefits will vary between individuals and thus it is essential to engage with groups of residents as to their interpretation of the fairness (or otherwise) of changes in the distribution of aircraft noise in order to inform the assessment of airspace change options and the ultimate decisions as to the outcomes. Our work set out to do just that by presenting groups of residents in a focus group setting with a virtual airport with which it was possible to explore perceptions of different airspace change concepts compared to a 'baseline' position representative of the current conventional distribution of aircraft around a route centreline.

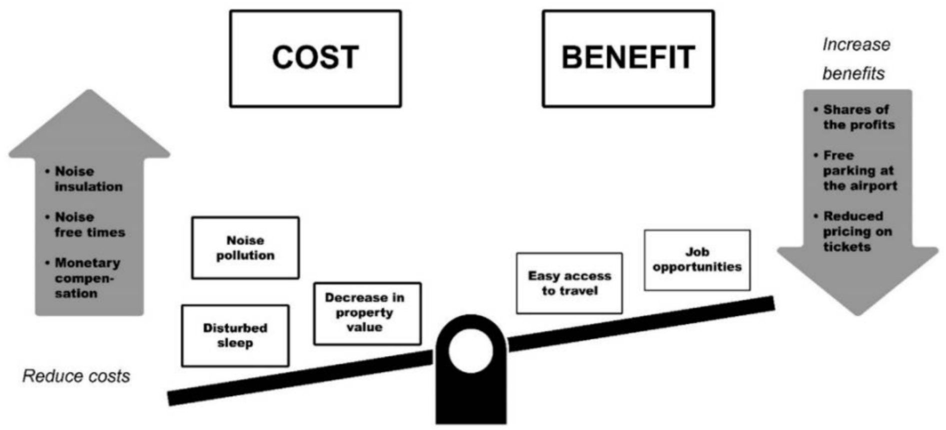

Figure 2: Illustration of balancing the individual cost-benefit ratio (from Hauptvogel et al)

In a total of 13 community focus groups, drawn from areas with differing experiences of aircraft noise around a UK airport, residents were presented with airspace change concepts related to a single westerly departure route turning to the north and splitting to the east (Figure 3). This 'baseline' situation illustrated that the vast majority of operations (98%) fall within a normal distribution around the route centreline extending 1.5km either side to the edge of the noise preferential route (NPR) and was taken as representative of aircraft operations pre airspace change modernization.

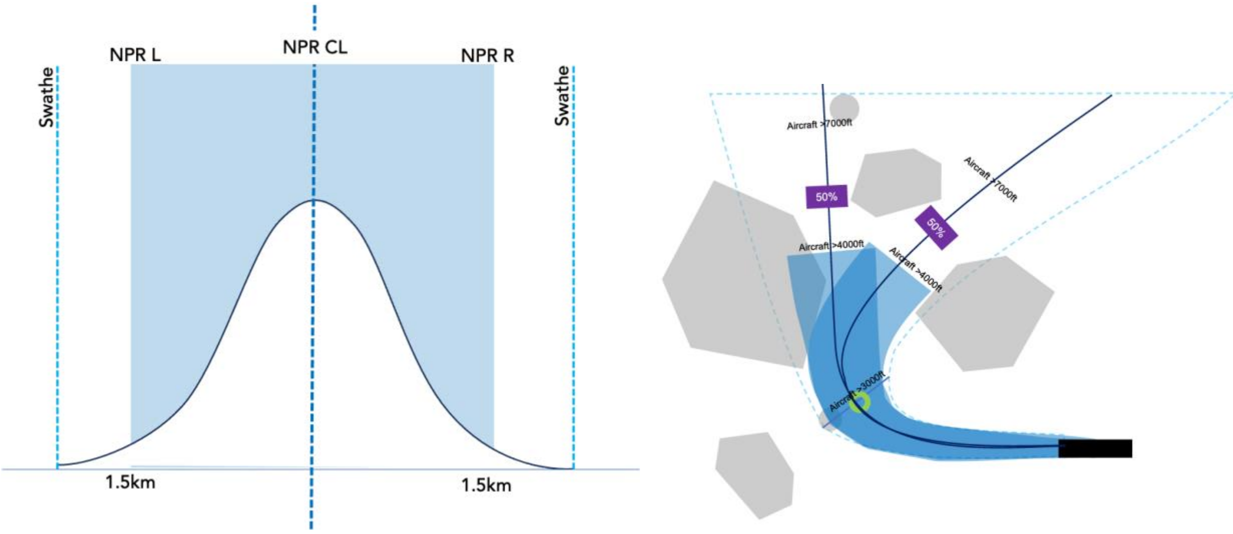

Figure 3: Virtual airport baseline concept showing aircraft distribution and location

Once the baseline had been described 4 different aircraft distribution concepts were presented to the FGs:

1. **Replication of the conventional route** – this was used as a starting point, harnessing the potential of performance-based navigation through airspace modernisation to ensure that aircraft fly the prescribed centreline more accurately and consistently, resulting in a much narrower band of distribution for the vast majority of movements within 0.5km each side of the route centreline.
2. **Limited dispersal of movements within the NPR** – here two sub-routes were created 750m to each side of the original route centreline and movements shared equally between them (assuming a normal distribution of flights across an area extending 0.5km each side of all routes). This spreading of aircraft numbers resulted in an increase in overflights around the new sub-routes and a corresponding reduction in flights on the original route centreline compared to both the baseline and Concept 1 scenarios.
3. **Wider dispersal within the NPR with noise consequences beyond** – this Concept extends dispersal to two further sub-routes 750m beyond those described in Option 2. Thus, movements are distributed evenly across 5 routes in total each accounting for one fifth of the original traffic normally distributed across 1km (0.5km each side of each route). This has the effect of pushing the concentration of the movements further away from the original route centreline with some overflights now beyond the NPR but within 0.5km of it. Consequently, there are noise exposure benefits for locations near the original route centreline as movements are spread outwards, with commensurate increases in noise events towards the outside edges of the NPR and beyond.
4. **Extensive sharing via a new route** – here a new route is located away from the original centreline and NPR to take a third of the traffic from the original route and create

significant noise benefits for those under the original route, whilst newly exposing an area previously not overflown.

To assist comprehension of the nature of change associated with each aircraft distribution concept, focus group participants were presented with graphical representation of the spatial distribution of aircraft movements along with an image of their geographical distribution (traffic for one day on an existing route of a UK airport was used for this purpose and manipulated to reflect the different patterns of spatial distribution). This was supplemented by images of the N65 contours for each concept and subsequent change in N65 events compared to the baseline (Figure 4).

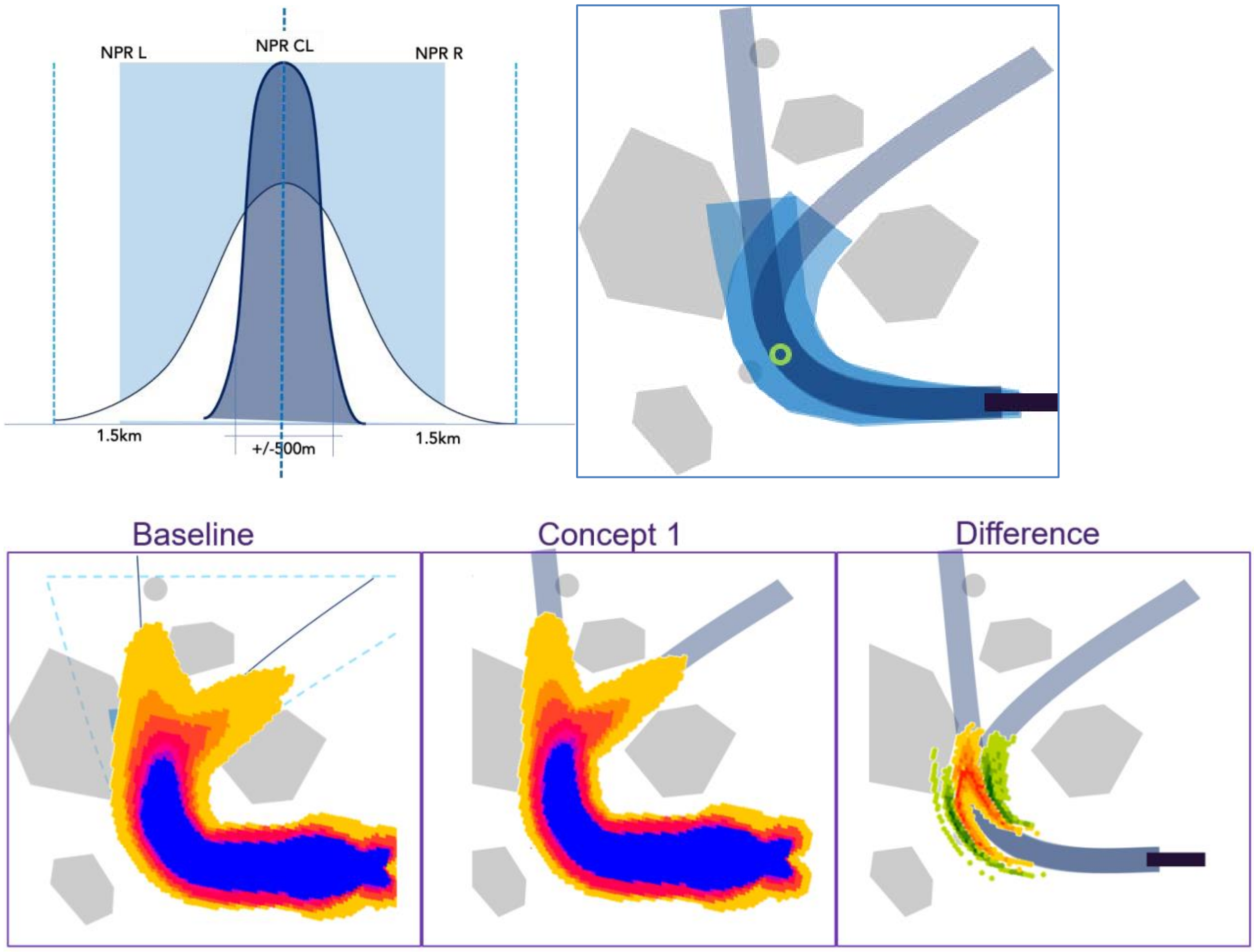

Figure 4: Movement distributions, location and associated N65 plots for Concept 1

It is worth noting that attempts were made to use the Leq metric to illustrate these changes, but this was found to be insensitive to the relatively subtle changes in the distribution of aircraft movements associated with Concepts 1,2 and 3 compared to baseline. In contrast, the N65 plots showed how concentration of movements resulted in an increase in the number of events experienced in locations closer to the route centreline with a corresponding reduction in events for locations towards the edge of the NPRs and beyond (Figure 4). Similarly, for concepts exploring the response to differing degrees of dispersal (Concepts 2, 3 and 4), the N65 plots highlighted increasing reductions in events closer to the centreline and increases in events further away from the existing route centreline as levels of lateral dispersal increased.

These illustrations using the virtual airport concepts stimulated open and considered discussion among focus group participants, whereby removing reference to specific locations reduced NIMBY bias and enabled discussions to reflect on the overall fairness for different patterns of increases and decreases in aircraft noise event outcomes. Participants were willing and able to express preferences and it became possible to relate these to changes in the spatial distribution of increases and decreases in N65 events to perceptions of fairness. Although each focus group was composed of participants drawn from areas experiencing different levels of exposure to aircraft noise around a UK airport (including some with no overflights and relatively little/no aircraft noise exposure), there was general consensus as to the opinions expressed in regarding the range of concepts presented for aircraft movement distribution:

- **Concentration of aircraft movements** along existing route centrelines was considered unreasonable as those already most exposed to aircraft noise would experience an increase in their noise burden
- **Some limited sharing of the burden of aircraft noise events** could help overcome adverse perceptions of concentration
- **Focusing the spreading among populations currently experiencing some noise exposure** could allay concerns over the extent of change against expectation
- **The greater the extent of change** (in the number and proportion of louder events), the more concerns are raised about impact/unacceptability. Thus, where dispersal options extend over wider areas (concepts 3 and 4) increasing concerns are raised about (for example):
    - Change against the expectations of residents
    - Conflict with existing land uses/designations (e.g. contrast with AONB features)
    - Likelihood of overflying populations with no or only limited experience of aircraft noise

Significantly, whilst the original intention of the focus groups was to use the virtual airport and associated airspace change concepts to explore perceptions of fairness and equity, responses to the airspace concepts focused on the issue of the fairness/unfairness of outcomes compared to the baseline almost exclusively. This appeared to be motivated by **concerns over the extent of change compared to an existing unequal distribution of noise events represented by the baseline**, rather than by a desire to establish more equitable distribution of movements across surrounding populations which, given the unequal distribution in the baseline, would have entailed significant change for most communities. Thus, **perceptions of distributional fairness in the case of change to a pre-existing distribution of noise events was dominated by the extent of change** and not the establishment of more even (equal) distribution of noise events.

In this respect the N65 information proved particularly useful as it:

- Demonstrated **sensitivity to relatively small changes in the lateral distribution** of aircraft movements within a route, not picked up by Leq measures.
- **Highlighted those areas experiencing increases or decreases in noise events** resulting from a change in the lateral distribution of aircraft movements
- Illustrated **change patterns strongly reflecting the perceptions of distributional changes and impacts**, thereby aiding understanding of the consequences of specific changes to aircraft movement patterns
- Had the **power to illustrate the geographical extent and consequence of concentration and sharing regimes**, providing the basis for transparent and comprehensive engagement with populations potentially affected by ACPs at different airports.

3. USING N65 DATA TO ILLUSTRATE THE EXTENT OF CHANGE

The focus group outcomes demonstrated that, at least in the context of airspace change where there is an existing distribution of aircraft, change in the spatial distribution of aircraft noise (events) lies at the heart of perceptions of fairness. The challenge for the researchers was therefore to devise a means by which the use of N65 data could supplement the existing CAP1616 process which currently is dominated by the assessment of total/aggregate change (using Leq metrics), by **illustrating more explicitly the extent of change in the distribution of noise events (N65) and the populations affected by that change**.

Given the importance attached to the extent of change a stepwise approach was designed to enhance community understanding of the implications of airspace changes, thereby empowering engagement in decisions that will ultimately affect them. This approach follows a logical path from:

1. An illustration of the spatial location of aircraft movements; through
2. The modelling of N65 heat map outcomes and change using flight track data; to
3. The characterization of the extent of N65 change by defining change bands and thresholds for change categories; and
4. Spatial presentation of N65 change categories; and finally
5. Quantifying populations in each change category – understanding the impact on people

3.1. Spatial and narrative presentation of options

The first step is to illustrate the options and provide an explanation of the basis for these options. An example illustration is shown below for the three airspace design concepts (Figure 5):

- Minimal change – the option that represents the minimum change to routes within the constraints of the PBN technology from the existing structure.
- Minimise population exposed – adopting an approach that seeks to actively concentrate flight paths and avoid population by introducing a new route.
- Sharing – an option that seeks to share aircraft across two areas.

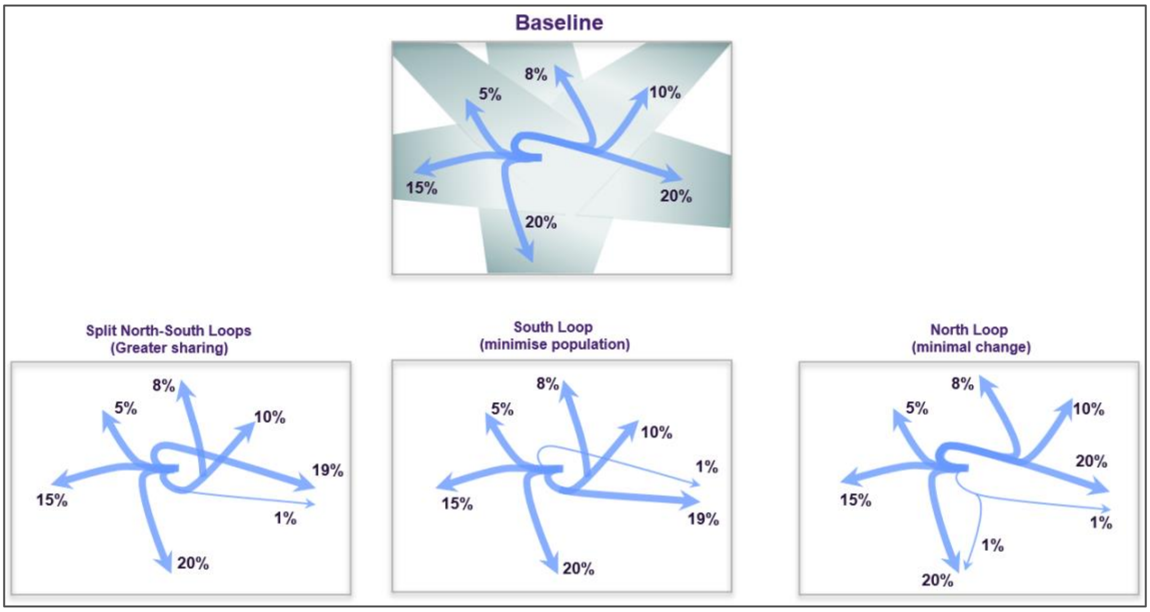

Figure 5: Airspace proposal illustrations with key goal intent (baseline at the top)

3.2. Spatial presentation of N65 and N65 change heatmaps

The second step is to illustrate the N65 spatial distribution for each of the options (and the baseline) and N65 change heatmap (relative to the baseline case). This is to simply illustrate the spatial pattern of noise events and change (Figure 6).

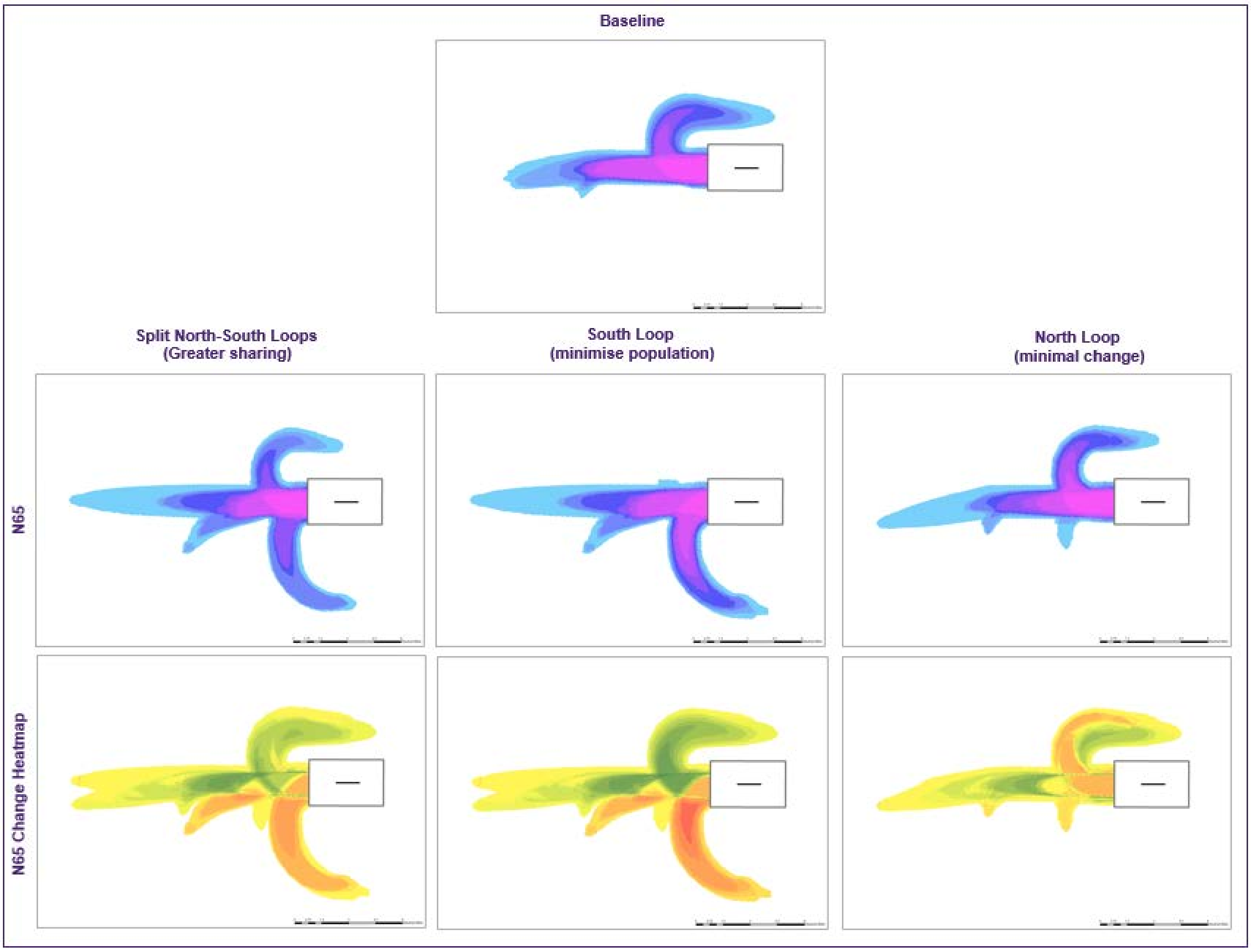

Figure 6: Spatial presentation of N65 and N65 change heatmaps

3.3. Illustrating the extent of change in N65 events

In this third step, N65 is characterised into meaningful and relatable bands and N65 change related to movements between bands to illustrate the degree of change.

A scale of N65 bands is proposed (Figure 7) based on the experience of aircraft events, ie. on average the number of events above N65 per period. For example, N65>4 is equivalent to 1 aircraft event every 4h and N65 >64 to at least one every 15mins etc. This is considered more meaningful than using bands based on a standard decimal system of 10, 20 etc which is often how N-above are characterised. Further the bands widen with increasing levels of exposure in recognition that smaller changes may be less discernable in areas with higher levels of existing noisy events. This proposed banding could be adapted at each airport to reflect the local operation.

N65 BANDS (16h)
N65 >4 (1 x 4h)
N65 >8 (1 x 2h)
N65 >16 (1 x1h)
N65 >32 (1 x 30mins)
N65 >48 (1 x 20mins)
N65 >64 (1 x 15mins)
N65 >96 (1 x 10mins)
N65 >192 (1 x 5mins)

Figure 7: N65 Change Bands

Five bands of N65 change were identified to enable greater understanding of the distribution of change arising from a design. These are summarised together with the definitions currently adopted to enable calculation of the populations exposed to this degree of change (Figure 8). Population can then be summed for each category. The general premise around the bands is that they reflect an expectation that, for those populations with a smaller number of events, a smaller change will be more noticeable/impactful as the proportional change will be greater than for the same change with higher numbers of events.

N65 Change Characterisation	
NEW (N65new)	**NEW (N65new)** Baseline N65 = 0 or N65 <4; increasing to N65>8, and an increase in average noise of at least +3dB LAeq.
INCREASE (N65+)	**INCREASE (N65+)** N65 band increases by at least 1, with an N65 increase of at least 8 or +45% (i.e. an increase of at least 1 aircraft every 2h)
NO CHANGE (N65nc)	**NO CHANGE (N65nc)** No change N65 band OR Band change +/- 1 with N65 change <+/- 8
REDUCTION (N65-)	**REDUCTION (N65-)** N65 band goes down by at least 1,N65 reduces by at least 8 or -33% (i.e. a reduction of at least 1 aircraft every 2h)
REMOVED – (N65rem)	**REMOVED – (N65rem)** N65 band goes down to Zero and N65 <=3, N65 >=4 in baseline,

Figure 8: Characterising N65 Change

3.4. Spatial presentation of N65 change categories

To provide local people with an informed understanding of the wider consequences of proposals the N65 change bands can be presented spatially (Figure 9). This enables understanding of the extent and area of changes.

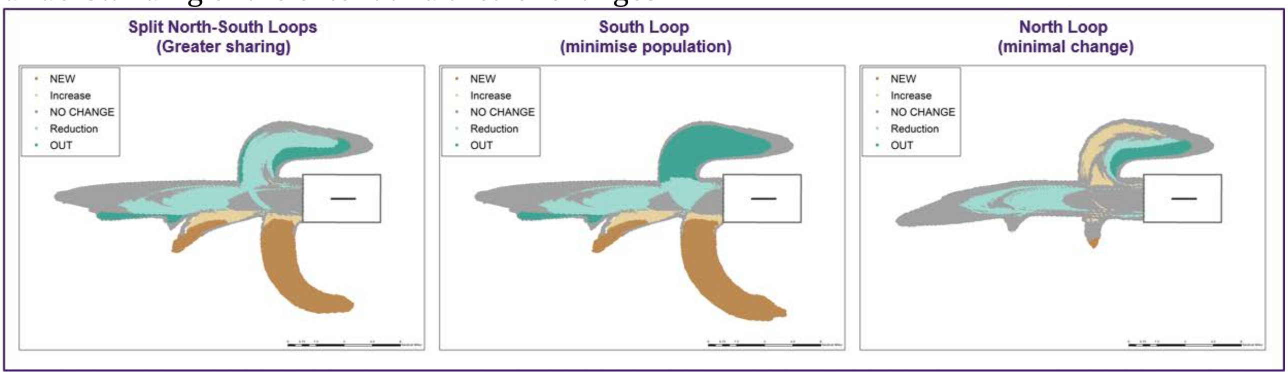

Figure 9: Spatial presentation of N65 change categories

3.5. Spatial and aggregate understanding of the consequences for local people

The above illustrations enable informed understanding of the spatial implications of proposals. The next step is to consider the implications for local people – change categories can be presented at postcode points using GIS which can be applied to identify community specific implications of change proposals and together with population at each postcode point can then be used to identify aggregate populations for each change category. Figure 10 illustrates the conversion of Figure 9 to postcode points to enable community level understanding of consequences.

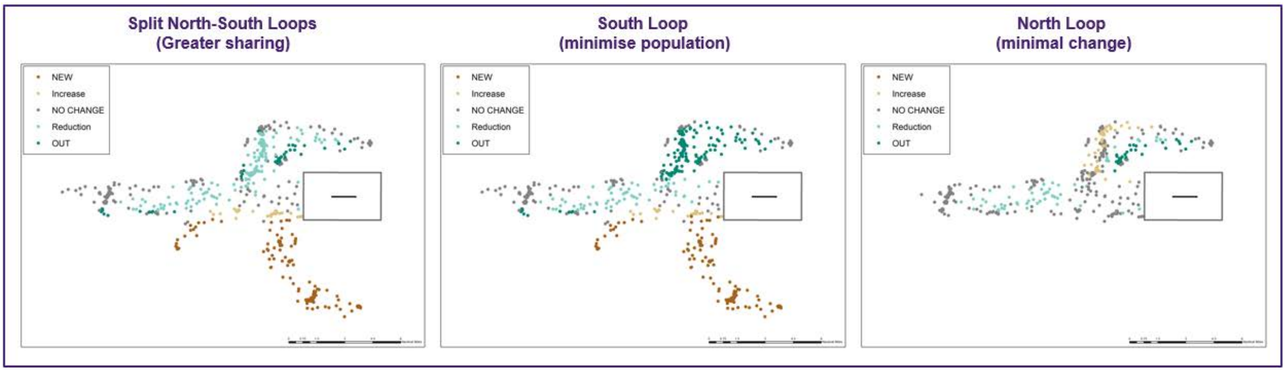

Figure 10: Spatial presentation of N65 change categories at postcode points

Summing the population for each noise change category and then presenting as a column chart to illustrate relative population in each change category provides greater understanding of the distribution of the consequences of proposals for the population as a whole (Figure 11).

Further **insights as to the impact on the total noise load, its distribution and the extent of change can be gained from introducing the concept of 'Person Events'**. Here the population is multiplied by the number of N65 events forecast to result from the implementation of an airspace concept at that location (total PEIs) adding to comprehension of the change in total PEI compared to baseline and the distribution of that PEI among change categories (Figure 12). A second PEI feature - focuses on the quantification and distribution of the difference in total PEI (PEI diff) between categories of change. This is achieved by multiplying the change in N65 at each postcode point by the population therein (Figure 13). The value of this assessment is that it sheds light on the PEI difference (both increases and decreases) experienced within each change category (rather than only the PEI outcome) as a result of the shift from baseline to the option being considered.

These PEI features help explain the aggregate, distributional consequences of changes from design proposals for local people. PEI could therefore also be used to highlight the extent and consequence of concentration or sharing regimes – providing the basis for transparent and comprehensive engagement with populations potentially affected by ACPs.

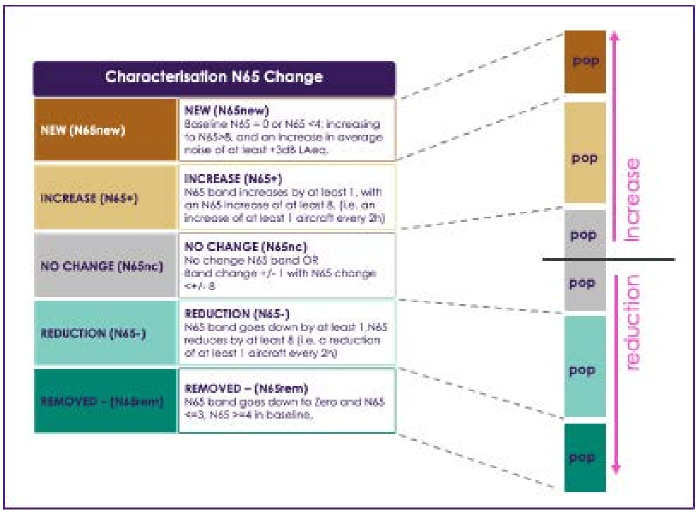

Figure 11: Considering Aggregate Consequences - Population and N65 change category

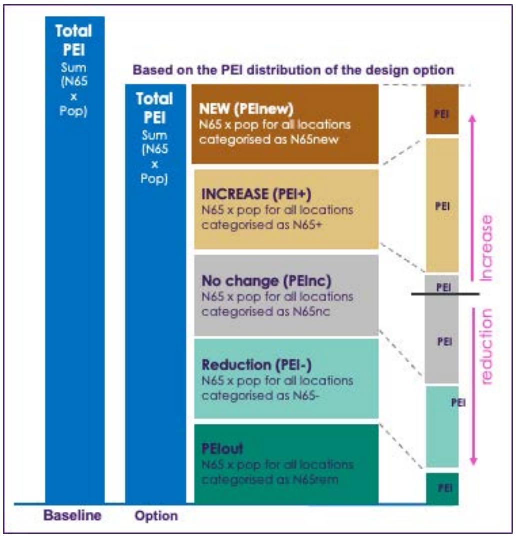

Figure 12: Understanding the distribution of change categories based on Option Total PEI

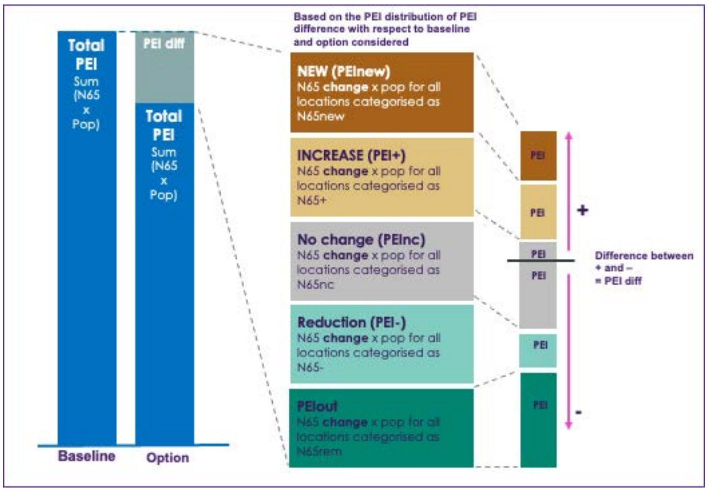

Figure 13: Understanding the distribution of change categories based on PEI difference between baseline and option

4. FINAL COMMENTS AND CONCLUSIONS

Given the strong link between the extent of change in the noise environment for communities resulting from an airspace change concept and perceptions of the (un)fairness of the outcome, this paper set out to develop a suite of metrics to highlight the extent of change (in N65 events) by way of facilitating more transparent dialogue with communities and thereby empowering them to influence ultimate airspace change decisions. If the preference for a particular outcome is known, at our case study airport community focus groups consistently favoured minimal change, then the risk of socially unacceptable outcomes can be linked to specific patterns of changes to N65 distribution and PEI consequences. For example, based on the preferences expressed in our focus groups the following objective noise metrics can be associated with the risk of socially unacceptable outcomes:

- Risk is minimised by maximising "PEI no change"
- Risk increases with increases in overall PEI; the risk reduces with greater PEI reduction
- There is an increased risk with increasing PEI+
- Increased risk with increasing population of N65+
- Increased risk with increasing PEInew

These risk factors linked to changes in the distribution of noise events can then be used to assess the relative risk of socially unacceptable outcomes arising from airspace change proposals which, as in the case in the UK CAP1616 process, have been sole assessed for their aggregate noise consequences. We argue that such an assessment can be used to refine proposals and also in their transparent presentation to communities, enabling more effective dialogue intended to promote community influence over final airspace change decisions.

A word of warning! Our study has shown that the risk of socially unacceptable outcomes from airspace processes is linked to perceptions of the extent of change to the noise environment and its distribution; however, how risk is linked to the direction of change in objective noise measures is intimately bound up with community preferences for a type of change – it may be in other circumstances, at other airports, communities see benefit in concentrating noise away from centres of population. Nevertheless, the suite of assessment tools proposed here is still relevant, simply their relationship to the risk of socially unacceptable outcomes changes. Thus, whilst the assessment framework may be universally applicable the link to perceptions of fairness and thus the (un)acceptability of outcomes needs to be explored with communities at every airport location. Similar comments can be made about the need to tailor the N-above threshold and associated banding of N65 change and changes between categories, to local circumstances

ACKNOWLEDGEMENTS
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