Quantifying Carbon in Airspace Noise Management Measures

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ABSTRACT

Civil aviation is being constrained by the poor understanding of environmental and operational interdependencies. Noise, and carbon emissions belongs to different physical spheres not directly comparable and managed under separate regulations. Noise reduction has been the priority for the aviation industry for many years, but this recently shifted to decarbonisation to achieve Net Zero emissions. Although carbon emissions are one of the main contributors to environmental impacts at global level, we still must consider local impacts, like noise, affecting environment and communities. We developed a process to describe the interrelations between carbon and noise emissions for Airspace Management. Through this process, overall environmental benefits and disadvantages of airspace change concepts, operational procedure changes are assessed, considering both the monetisation of harmful effects and the costs of the carbon emissions impacts on the environment. While some designs provide benefits for noise or carbon emissions, others might provide minimum benefits despite the high costs associated either for noise or carbon, or their effectiveness might depend on the location where they occur. In the context of sustainable aviation, the process we developed provides a tool for airspace developers to identify the trade-off between noise and carbon emission to design an effective sustainable airspace.

1. INTRODUCTION

Civil aviation is becoming increasingly constrained by the need to balance environmental, operational, and economic interdependencies. Whilst carbon emissions are one of the main contributors to environmental impacts, especially at global level, it is important to also consider the other environmental impacts, such as noise, which can have more a local impact on the environment and local communities.

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Each of these environmental impact contributors belongs to different physics domains, which are not directly comparable, are often managed under separate policies and regulations, and do not have common cost functions other than their monetary values for a meaningful comparison, highlighting the fact that to date there is still a poor understanding of the interdependencies that relate environmental, operational and socio-economic factors.

Challenges can occur when seeking minimise the impact of one environmental aspect which does not necessarily mean that all others are reduced. In fact, decisions made to manage an individual environmental aspects could be in direct conflict with the management and impacts of another.

An example of this conflict arose less than 20 years ago with the Airbus A380, where fuel burn efficiency was sacrificed to some small extent to meet the inflexible noise regulations. However, noise reduction has been too small to make any noticeable difference to people on the ground, while the whole-life cost of the increased fuel burn is considerable [1] [2].

In less than a decade the priorities of the aviation industry changed with the industry now focused mainly on fuel efficiency and on the process of decarbonisation to meet the net zero carbon targets [3].

When considering airspace design in particular, an understanding of the potential environmental effects is key to ensuring that certain outcomes are prioritised and appropriate decisions are reachedFor instance, this is part of the consenting process in the UK [4]. For instance, a priority could be to trade more fuel burn and associated carbon emissions for reducing the population exposed to aircraft noise nearer to the airport. Vice versa, prioritising fuel efficiency by having more direct routes could result in more densely populated areas been overflown.

When considering how airspace is managed, each of these environmental aspects requires detailed consideration.

2. BACKGROUND

The considerable increase of the air traffic has implied a significant impact upon the environment during the last three decades gaining importance for aircraft manufactures, air traffic authorities and policy makers around the world, in order to reduce the environmental impact caused by aircraft operations.

Key targets have been set at European levels that long for a zero pollution vision to be achieved by 2050, To steer towards the 2050 vision, 2030 targets to speed up emission reduction have been set. Among these there are [5]:

- Reduction of more than 55% the health impacts (premature deaths) of air pollution;
- Reduction by 30% of the share of people chronically disturbed by transport noise.

These targets are not aviation specific but nonetheless potentially introduce political drivers for the entire industry. However, the quantification of the overall effects is difficult due to efforts in finding an appropriate model that can properly describe the interdependencies between noise and emissions as to date no such model has been identified to express interdependencies through a single applicable metric [2].

Interdependencies between noise, NO_x and CO_2 emissions, for example, are complex and require careful evaluation prior to regulatory, operational or design decisions. As regulations become more stringent, the relevant trade-offs become more difficult to address.

The identification of a sensible trade-off between emissions and noise should be therefore one of the main objectives of the aviation industry.

In this identification exercise it is important to recognise that interdependencies can be (1) technological, i.e. where the interactions between noise, CO_2 and NO_x emissions are dependent on engine technologies and airframe, and (2) operational, i.e. where the interactions of the different emissions are dependent on the airspace management and aircraft operations [2].

The focus of this paper is on the operational interdependencies, particularly those ones relative to the airspace design and the trade-off between noise and CO_2.

3. METHODOLOGY

In order to describe the interrelations between carbon and noise emissions in the airspace design, a process of assessment of the overall environmental benefits and disadvantages of operational procedure changes and airspace designs. Under UK policy, such considerations are addressed through the monetisation of harmful effects from the noise impacts and the costs of the carbon emissions impacts on the environment [6].

3.1 Operational procedure evaluation

To support the airspace designers in understanding what operating procedures can be implemented to reduce noise and/or CO_2 emissions as part of the airspace modernisation, an evaluation of the single components is undertaken. This evaluation aims to understand the trade-off implications and potential consequences at certain points under the flight paths for noise and carbon.

It takes into account the SEL footprint and the fuel burn, which is used as a proxy for CO_2 emissions. The evaluation is carried out on individual tracks for a range of aircraft types (usually the most common types of an airport fleet mix among medium small heavy and heavy bodied). Flight profiles are created using aircraft noise model software to replicate the operating procedure of the selected aircraft types.

SEL footprints are overlaid on data such as population to demonstrate the potential consequences of each procedure. The difference in fuel burn of the compared procedures is used to provide an estimate of the cruise miles that are saved by operating one procedure from the another.

The evaluation of operational procedure is then used to inform the design of the airspace change concept options.

3.2. Monetisation of the noise impact

The process to monetise the effects of noise in terms of harmful effects consists in quantifying the noise impact through aircraft noise models (e.g. AEDT, INM, EUROCONTROL's IMPACT) for both the existing airspace and the concept options for the airspace change in the year of the airspace change implementation and a forecast year. The results of the model are to be interpolated with population data to estimate the number of people and households exposed to different levels of aircraft noise. For each change in average noise level, a monetary value is assigned for the change of health impacts (e.g. annoyance, acute myocardial infarction, dementia, stroke, and sleep disturbance) and the consideration of other noise related effects such as respite. These values are usually based on the latest evidence on the relationship between noise exposure and harmful effects (e.g. WHO Environmental Noise Guidelines for the European Regions).

A decrease in noise exposure will result in a reduction in costs associated with health impact (i.e. an improvement in health impacts), whereas an increase in noise exposure will result in an increase of the costs. No change in noise exposure will result in no change in costs and therefore health outcomes.

3.3. Costs of the carbon emissions impacts on the environment

The methodology of the Fuel Burn and Carbon assessment effectively only takes into account the difference in the track lengths of each design option and the associated fuel burn.

For each concept options, the length of each track is calculated and used to assess the fuel burn of each aircraft type on each track.

Fuel flows for each aircraft type included in the fleet mix are averaged per NMi and used for all the tracks associated with the airspace baseline and proposed concept options. The fuel burns calculated for each aircraft type is combined to provide a total fuel burn for the airspace options.

Carbon emissions are estimated multiplying the fuel burn expressed in mass of kerosene by the 3.18 factor for Carbon Equivalent emissions [7], and their costs calculated through governmental Greenhouse gas emissions values which represent a monetary value that society places on one tonne of carbon dioxide equivalent

3.4. Environmental Interdependencies Matrix

The costs associated to the noise impacts and the carbon emissions can be visualised through a cartesian plane, where the X axis represents the costs associated with noise impacts, the Y axis those one associated with the carbon emission and the origin (0,0) represents the current scenario. Each of the 4 quadrant represent the possible environmental combinations for noise and carbon interdependencies as shown in the Figure 1.

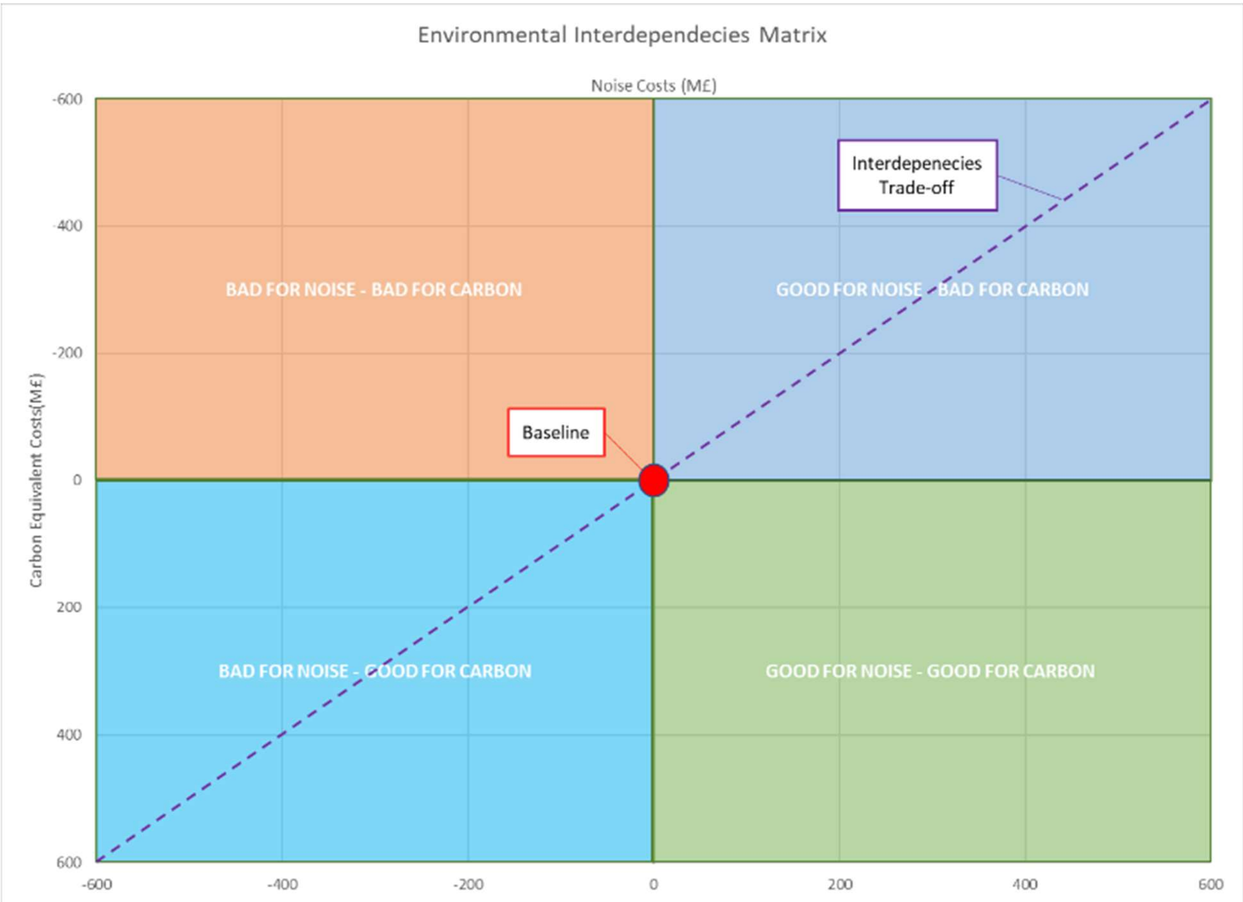

Figure 1: Environmental Interdependencies Matrix

Each airspace design option that is assessed can be represented as a point on the plane. The overall environmental benefits and disadvantages of airspace change options can be evaluated considering where the point is represented on plane and in which quadrant, and sensible trade-offs between emissions and noise identified.

4. APPLICATION OF THE METHODOLOGY TO AIRSPACE CHANGE ENVIRONMENTAL ASSESSMENT

This section considers the results which can be obtained using the methodology outlined in Section 3 as part of the environmental assessment of different airspace design approaches.

The evaluation of the operational procedures can be carried out initially to inform the design. The figure below (Figure 2) for instance presents the comparison of two operational procedures (level segment and continuous climb) for three different aircraft types (7773ER, A320-232 and A320neo).

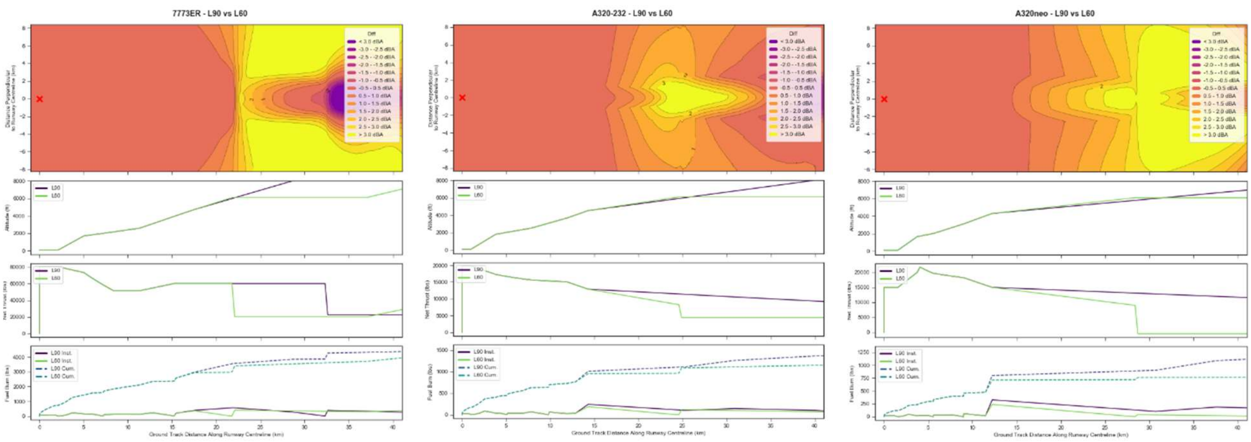

Figure 2: Comparison of two operational procedure for different aircraft types.

The results show that for noise, aircraft noise event levels depend on the procedure and on the type of aircraft. Any decision with respect the implementation of the two procedures need to take into consideration the location of the population under each route and the likely level and mix of traffic. Fuel burn differences associated with the two procedures are also aircraft dependent. Comparing the fuel burn per nautical mile at 10,000ft, for 7773ER levelling off was expected to be more fuel efficient than climbing straight at cruise level (without any track extension). For the A320-232, level segment became more efficient if a track extension of 17 NMi or more was used to avoid leveling off.

The evaluation of this and other operational procedure can be used to inform the design of airspace in a manner where noise and carbon impacts can be traded.

The calculated costs of noise impact and the carbon emissions for all the concept options can then plotted into the Environmental Interdependencies Matrix to identify overall environmental benefits and disadvantages of the proposed airspace change options (Figure 3).

In this example, minimising the environmental impact of one environmental aspect does not necessarily mean that the other is reduced. One option was found to provide benefits for carbon emissions only, while others might provide relative benefits for noise but with a high costs associated to carbon emissions. A group of options was instead found to provide noise benefits off-setting the impacts of the carbon emissions.

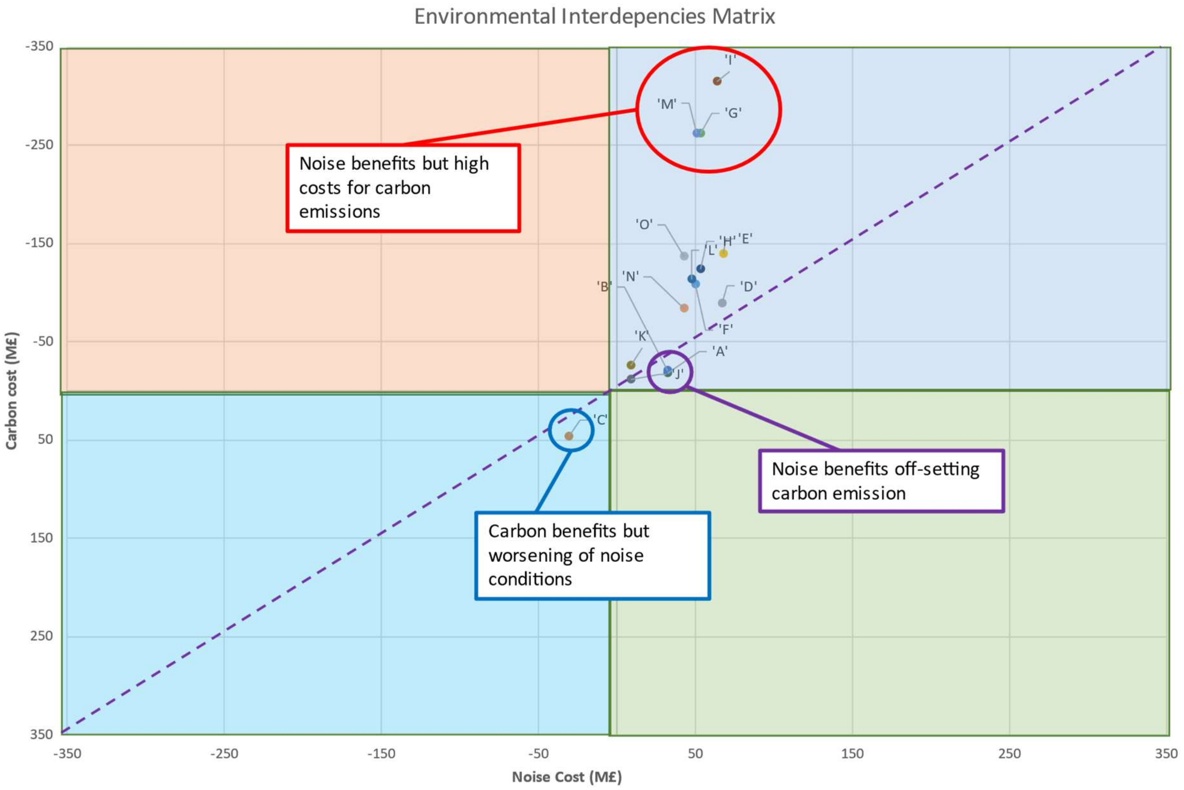

Figure 3: Environmental assessment and trades-off

5. CONCLUSIONS

The considerable increase of the air traffic in the last thirty years and its relative impacts upon the environment, gained importance among aircraft manufactures, air traffic authorities and policy makers which are aiming to find solutions to reduce the effects caused by aircraft operations on the environment.

At European level, ambitious targets have been set aiming for a zero pollution vision to be achieved by 2050. However, the quantification of the overall emissions and their relative effects is being difficult due to poor understanding of the environmental, operational, and economic interdependencies. When considering how airspace is managed, these interdependencies' effects require detailed considerations and in the process of airspace modernisation, decisions are to be made identifying sensible trades-off.

This paper focused on the operational interdependencies, particularly those ones relative to the airspace design and the trade-off between noise and CO_2.

In order to describe the interdependencies between carbon and noise emissions to help airspace change design, we have developed a process which assesses the overall environmental benefits and disadvantages of airspace change concept options, considering both the monetisation of harmful effects from the noise impact and the costs of the carbon emissions impacts on the environment.

The costs associated to the noise impacts and the carbon emissions can be evaluated through the Environmental Interdependencies Matrix that we have developed which presents the possible environmental combination effects for noise and carbon interdependencies, and their trades-off.

The developed process was tested over 18 departure concept options for the airspace change proposal of a UK two runway airport. By considering the costs associate to noise (taking into considerations also Respite) and carbon emissions. By plotting into the Environmental Interdependencies Matrix the costs associated to noise and carbon emission, no options were found to improve noise and carbon emissions which confirm the fact that minimising the environmental impact of one environmental aspect does not necessarily mean that the other is reduced. Instead, it was possible to identify a group of options that provided noise benefits off-setting the impacts of the carbon emissions.

In the context of sustainable aviation, the process we developed can be a tool for airspace developers to identify the trade-off between noise and carbon emission to design effective sustainable airspaces.

The process can be further developed identifying sensitive environmental threshold which provides acceptable environmental performances and trades-off depending on airports which can further assist the design of a sustainable airspace.

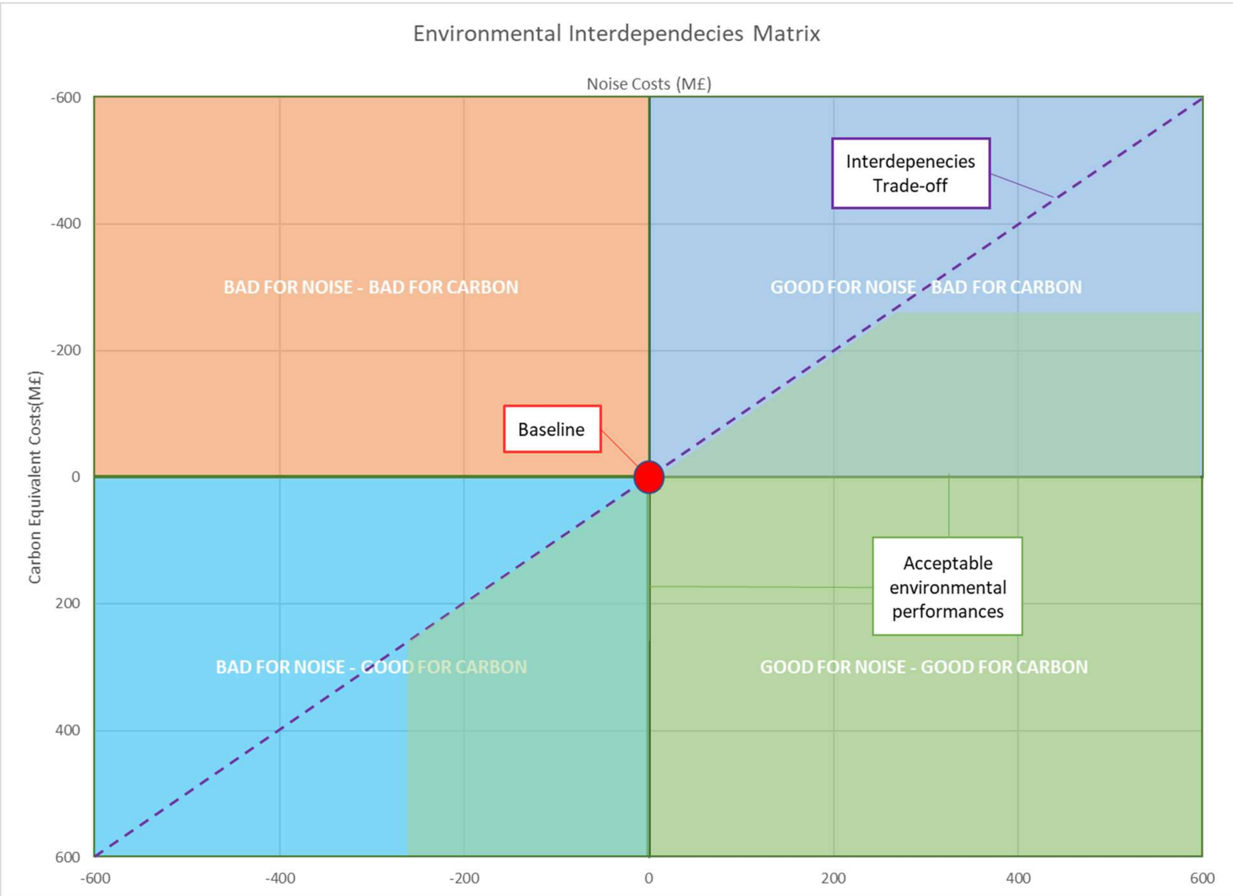

Figure 3: Environmental Interdependencies Matrix with possible environmental targets

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