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Technical note

Airport noise modelling for strategic environmental impact assessment of aviation

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ABSTRACT

As projected by different agencies the aviation market will experience a significant increase in air traffic demand over the next decades, driven by the large demand of the Asia-Pacific region. To overcome the further deterioration of the quality of life of communities living around airports, the various aviation stakeholders are required to explore scenarios with different technology options, flight procedures, and fleet replacement strategies. Of course, the assessment of aviation scenarios must be addressed in a more integrated manner than hitherto, where noise, air quality and carbon release are considered. For such purpose, simplified airport noise models are required to overcome the important input data requirements and computation complexity of detailed airport noise models, and also to ensure compatibility against other environmental and economic models. This paper analyses the applicability and discusses the unavoidable limitations and advantages of existing simplified airport noise models within the context of multi-disciplinary strategic environmental impact assessment of aviation. Simplified airport noise models satisfying the above requirements and developed to be coupled with technology evaluators, e.g. Rapid Aviation Noise Evaluator (RANE) model (Torija et al., 2017), can inform policy decisions about which future technology platforms would be likely to be the most environmental efficient when considered holistically. Based on the specific conditions tested, the straight-out trajectory assumption and the use of generic aircraft types seem valid approximations for computing aviation noise outputs.

1. Introduction

To ensure the sustainability of the aviation sector, appropriate actions are required to mitigate community noise and air quality problems around airports, and to reduce fuel consumption. With the substantial increase in air traffic demand as forecast by several agencies [1–3], aviation industry is investing a significant effort in the development of ongoing research programs for enhancing fuel-burn efficiency, and reducing the mission of air pollutant and noise. Along this line, the Advisory Council for Aviation Research and Innovation in Europe (ACARE) and NASA have put forward fuel-burn and emissions reduction goals for aircraft entering into service in the long-term: Flightpath 2050 [4] and N + 3 [5] programs respectively.

The assessment of the noise impact of future scenarios requires fleet-level studies where variables such as air traffic demand, fleet composition, technology options, and rate of penetration of novel aircraft are considered. Also, diverse flight procedures for minimizing aircraft noise around airports will need to be assessed [6]. In these future scenarios, although there is an agreement that a considerable increase in air traffic will take place, the projections of different agencies differ significantly [1–3]; also, a large number of novel aircraft concepts under development or projected to be developed can be found in literature [7]. Therefore, the fleet-level prediction of noise for future scenarios is a highly combinatorial and computationally expensive problem, so that detailed airport noise models such as the FAA's Integrated Noise Model (INM) [8] or the UK Civil Aircraft Noise Contour Model (ANCON) [9] are not always practical at a fidelity-level required in preliminary strategic planning and decision making procedures [10]. For this reason, a number of simplified airport noise models for fleet-level studies have been developed. Although, each of these models compute noise outputs using a different approach, all of them are rapidly computable and have a simple formulation [11].

On the other hand, the decision on technology investment for minimizing environmental externalities of aviation requires an integrated and multi-disciplinary strategic environmental assessment. For this purpose, as proposed in this paper, airport noise models need to be incorporated in integrated tools [12] (Fig. 1), ensuring compatibility against input and output requirements in other environmental and economic models [13].

This paper analyses the applicability of a number of simplified

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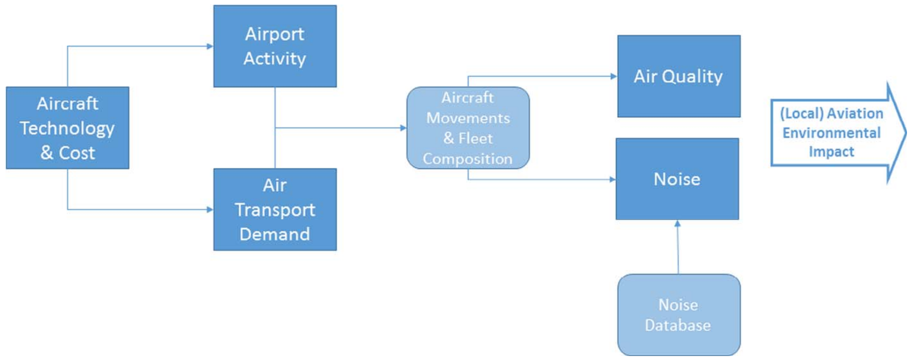

Fig. 1. Structure of an integrated model for assessing aviation environmental impact (modified from [12]).

airport noise models within the context of strategic aviation environmental impact assessment, discussing their limitations and advantages. Moreover, this paper examines and discusses the validity of two common assumptions in most of the simplified airport noise models reviewed: (i) straight-in – straight-out trajectory and (ii) the use of generic vehicles as representative of an aircraft category.

2. Review of simplified airport noise models

This section overviews some of the simplified airport noise models more often cited in the literature, describing their approach for computing noise outputs.

Powell [14] derived the analytical basis for relationship between noise contour areas and noise levels at certification measurement points.

In Fig. 2, the sound-level at all points on the contour (outer line) is equal to a given value L, and the sound-levels at the flyover (x_{FLY}) and sideline (y_{SL}) certification points are L_{FLY} and L_{SL} respectively. For deriving this analytical basis:

(i) The power and acoustic output at the aircraft is assumed constant.
(ii) The sound-level is inversely proportional to distance assuming spherical spreading. Thus,

$$L_{FLY} = L + 20\cdot\log_{10}(a/a_{FLY}) \quad (1)$$

$$L_{SL} = L + 20\cdot\log_{10}(b/b_{SL}) \quad (2)$$

(iii) $(x/x_{FLY}) \approx (a/a_{FLY})$ and $(y/y_{SL}) \approx (b/b_{SL})$
(iv) The noise contour area is proportional to the product of the length and width parameters of the noise contour (x and y in Fig. 2), and therefore,

$$Area \propto (x_{FLY}\cdot y_{SL})\cdot\left[\frac{10^{(L_{FLY}+L_{SL})/20}}{10^{(2\cdot L)/20}}\right] \quad (3)$$

Dikshit and Crossley [8] developed a noise model that approximates INM-predicted area within the 65 dB Day-Night level (DNL) contour. Based on a set of INM noise experiments at a limited set of system airports, the noise model estimated the 65 (dBA) DNL contour area as a linear function of the number of aircraft operations (differentiating between passenger and cargo aircraft). The model uses the Noise Energy Equivalent (NEE) computed as $10^{EPNL/10}$ from the published certification sound-levels at the flyover, sideline and approach certification points. The noise model also accounts for the effect of different Maximum Takeoff Weights (MTOW) on the takeoff sound-levels. This model was used to develop the noise module for a fleet-level evaluation of environmental impact of new aircraft [15].

The FAA's Area Equivalent Method (AEM) "is a mathematical procedure that provides an estimated noise contour area of a specific airport given the types of aircraft and the number of operations for each aircraft" [16]. Based on the concept of "equivalent operations" [10], the airport 65 dBA DNL contour area is estimated for an equivalent number of operations of a reference aircraft [17]. The change in contour area is then determined by a scaling parameter relative to a change in number of operations [16]. AEM is used as a screening procedure to determine whether a detailed study (conducted with any detailed airport noise model, such as INM) is required.

Bernardo et al. [17] developed a noise model, called Airport Noise Grid Integration Method (ANGIM), where (single-event) aircraft departure and approach sound exposure levels (SEL) grids are pre-calculated assuming straight ground tracks and standard-day sea level atmosphere. Once the schedule of operations is defined, an airport-level SEL grid is computed as logarithmic additions of the SEL grids of all the events occurring during that flight schedule. For cases with multiple runways, the runway-level SEL grids are manipulated (rotated, translated and interpolated), and then summed to yield an airport-level SEL grid. Noise contour areas are then calculated from airport-level grids. This model was validated against INM, and also used for assessing fleet-level noise impacts of projected technology improvements [10].

Li et al. [18] developed a noise model for preliminary aircraft noise-

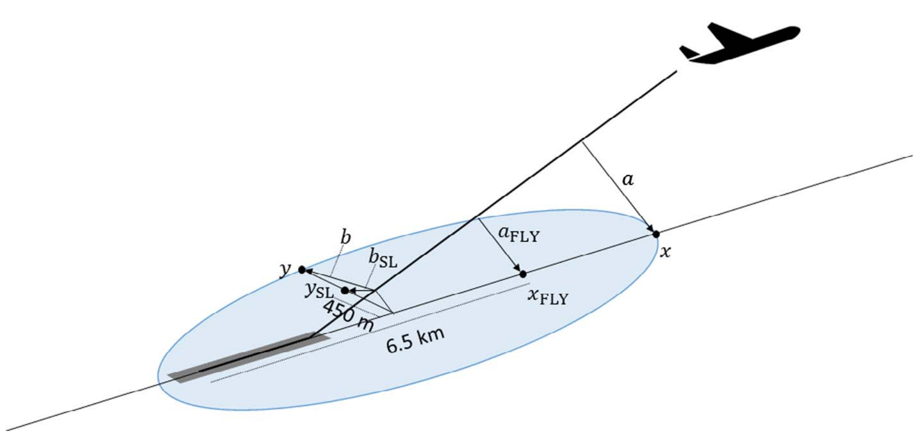

Fig. 2. Typical departure noise contour and geometric relationships to noise certification points (modified from [14]).