EVOLUTION OF NOISE METRICS IN FUTURE AVIATION SCENARIOS IN THE UK

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The Department for Transport of the UK (DfT) estimates an increase of 90% of air transport movements by 2050 compared to 2010. In order to offset such increase in the number of aircraft operations and avoid the consequent increase in noise impact on exposed populations, aviation industry is working on the development of new technologies for noise reduction. Within this context, organizations such as the International civil Aviation Organization (ICAO) and the Advisory Council for Aviation Research and Innovation in Europe (ACARE) have established strategic research agendas and targets for noise reduction in future aircraft. In this work the results of a parametric study are presented, where the 57-dBA L_{Aeq} contour area for the overall UK is estimated for a number of projected (i) aviation growth rates, and (ii) noise reduction rates due to new technologies. Moreover, because of the diverse airframe and engine technologies, different noise reduction rates are estimated at each certification point (lateral, flyover and approach). From the estimation of some acoustical metrics (L_{Aeq}, and Noise and Number Index – NNI type metric) at each certification point, the effectiveness of each considered noise reduction rate in reducing aviation noise around airports is discussed.

1. Introduction

Several organisations [1, 2] agree in forecasting a significant increase in the demand for air transportation for the next 40 years. Such increase in the number of aircraft movements will consequently lead to an increase in the impact of aviation noise and emissions on the population near airports.Although aircraft operations have significant impacts on air quality, climate change and fuel consumption, aircraft noise annoyance undoubtedly has the largest social impact on the airports´ surrounding communities [3]. Also, aircraft noise should not only be considered as a cause of annoyance but also a concern for public health and environmental health [4].

To avoid the potential increase in aviation noise impact on exposed populations as a consequence of the estimated growth in air traffic, the aviation industry is aggressively researching low-noise technology in order to provide much quieter aircraft for the future replacement of the current ones. In this framework, the Independent Experts Panel (IEP2) appointed by the ICAO Committee on Aviation Environmental Protection (CAEP) delivered noise reduction goals for the 'Mid Term' (2020), focusing essentially on current and imminent technology, and for the 'Long Term' (2030) where novel aircraft and engine concepts were considered [5]. Also, the Advisory Council for Aviation Research in Europe (ACARE) reported the long term vision for aviation in Europe, Flightpath 2050 [6]. In Flightpath 2050 a 65% (or 15.0 EPNdB) reduction over reference '2000 levels' is set as the noise reduction goal at each certification point (i.e. Lateral, Flyover and Approach) for 2050.

Under such perspectives, the different stakeholders, i.e. manufacturers, airlines, airports and government are required to address projections and analyses in order to avoid serious deterioration of important relationships between airports and surrounding residents, and to ensure a sustainable development of the aviation sector. For this reason, with the main goal of assessing the variation in aviation noise impact with the growth of traffic demand and with the entry into service (EIS) of quieter aircraft, this paper investigates the evolution of a number of noise metrics for some potential future scenarios in the UK.

Firstly, as the most widely used metric for aviation noise impact assessment, the 57-dBA L_{Aeq} contour area is estimated for different future scenarios. Regarding the air traffic growth, two projections are considered: (i) the Department for Transport in the UK (DfT) central scenario [1] and (ii) the EUROCONTROL projection for the North West European region (ESRA NW) [2]. Also, five noise reduction rates due to technology improvements are considered: (i) baseline scenario, (ii) ultra-low-noise scenario and (iii) ultra-low-CO_2 scenario (assuming the replacement of current short-haul aircraft with contra-rotating open rotors, CROR) as proposed by the Sustainable Aviation Noise Roadmap [7], and also (iv) ICAO CAEP IEP2 [5] and (v) Flightpath 2050 [6] noise reduction goals.

Secondly, because of both the different balance between engine and airframe sources for departure and landing operations [8], and the diverse engine and airframe technologies, different noise reduction rates are projected for each certification point [5]. Thus, from the estimation of noise metrics at each certification point, the performance of each noise reduction projection in lowering noise impact for approach and (each stage of) departure operations is analysed and discussed.

On the other hand, the ANASE research [9] found that a noise and number (NNI) type metric seems to provide a stronger basis than L_{Aeq} for estimating future noise impact as a result of changes in number and types of aircraft. Therefore, both L_{Aeq} and a NNI type metric are calculated at each certification point for each of the five noise reduction projections evaluated.

2. Methodology

2.1 Aircraft database

For the purposes of this paper, and based on [5], four aircraft categories are considered, i.e. Regional Jets (RJ), Small/Medium Range Twin (SMRT), Long Range Twin (LRT) and Long Range Quad (LRQ). For each of these categories, a reference aircraft of the current ‘year 2000 generation’ is selected: (i) Bombardier CRJ-900 for RJ, (ii) Boeing 737-800 for SMRT, (iii) Airbus A330-343 for LRT and (iv) Boeing 747-400 for LRQ.

Three aircraft generations are considered: generation G0 (current aircraft in service), generation G1 (‘imminent’ aircraft generation entering service over the next few years, and incorporating novel technology already developed) and generation G2 (‘future’ aircraft generation incorporating novel noise-reducing airframe and engine designs still under research and development). For calculating sound-levels, a linear transition from G0 to G1 and from G1 to G2 is assumed, based on the data showed in Table 1.

Table 1: Transition dates for aircraft generations G1 and G2 [7].

Aircraft Category	Generation G1		Generation G2	
	EIS_{G1}	End of Transition	EIS_{G2}	End of Transition
RJ	2015	2045	2040	2060
SMRT	2015	2045	2025	2050
LRT	2014	2040	2040	2060
LRQ	2007	2027	2040	2060

2.2 Technology and aviation growth scenarios

The sound-levels are calculated for a number of potential future scenarios, based on different aviation growth rates and noise reduction projections due to technology improvements in generation G2.

As indicated above, two aviation growth projections are considered, the forecast reported by the DfT for the UK (DfT-Central) and the forecast reported by EUROCONTROL for the North West European region (ESRA NW), both for the period 2010-2050 (Table 2). The DfT-Central forecast assumes the aircraft movements to grow annually by varying amounts between 0.8% and 2%, resulting in an overall growth of 89% by 2050. This forecast also assumes the same growth rate for all the categories. As a consequence of the significant expansion of the Asian and South American aviation markets, the ESRA NW projection assumes a much bigger increase in the number of (long-haul) inter-European movements (2.1% p.a.) compared to the (short-haul) intra-European movements (0.7% p.a.). Currently, short-haul movements highly dominates the UK aviation market, so assuming the growth rates for short- and long-haul movements, an overall growth of only 44% by 2050 is estimated.

Table 2: Aviation growth rates p.a. for the DfT-Central and ESRA NW projections.

Aviation Growth Projection	Period									
	2010 - 2011	2011 - 2012	2012 - 2015	2016 - 2020	2021 - 2025	2026 - 2030	2031 - 2035	2036 - 2040	2041 - 2045	2046 - 2050
DfT-Central	0.8%	0.8%	0.8%	1.8%	2.0%	1.6%	1.7%	1.6%	1.9%	1.3%
ESRA NW (Short-haul)	3.1%	-2.4%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%
ESRA NW (Long-haul)	3.1%	-2.4%	2.1%	2.1%	2.1%	2.1%	2.1%	2.1%	2.1%	2.1%

The noise levels for the aircraft generation G1 (L_{G1}) were obtained from [7]. For the generation G2, the noise levels (L_{G2}) (for each certification point) were estimated using the data showed in Tables 1 and 3, as follows:

$$L_{G2} = L_{G1} - \left(NR \cdot (EIS_{G2} - EIS_{G1})\right) \quad (1)$$

As mentioned above, five scenarios are considered. SA Baseline (low noise reduction technology), Ultra Low Noise (advance noise reduction technology) and Ultra Low CO2 assume the same noise reduction rate (NR) for the three certification points. In Ultra Low CO2 scenario, CROR are assumed to replace current short-haul aircraft, so no improvement was assumed for RJ and SMRT categories. The ICAO CAEP IEP2 scenario assumes different NR for each certification point. The NR of ICAO CAEP IEP2 and Flightpath 2050 scenarios were derived from the comparison between L_{G1} (at EIS_{G1}) and the target noise level, e.g. current '2000 noise level' -15dB (by 2050) for Flightpath 2050. It should be noted that different reductions in L_{G1} as compared to current '2000 levels' are found for each certification point, reason why different NR are observed at each certification point for Flightpath 2050 scenario.

Table 3: Noise reduction rates p.a. (NR) due to technology improvements. Note that ICAO CAEP IEP2 and Flightpath 2050 scenarios provide different NR for Lateral (Lat), Flyover (Fly) and Approach (App) certification points.

Aircraft Category	SA Baseline	SA Ultra Low Noise	SA Ultra Low CO2	ICAO CAEP IEP2			Flightpath 2050		
				Lat	Fly	App	Lat	Fly	App
RJ	0.10	0.30	0.00	0.25	0.05	0.23	0.32	0.28	0.41
SMRT	0.10	0.30	0.00	0.51	0.54	0.33	0.31	0.45	0.43
LRT	0.10	0.30	0.30	0.40	0.03	0.22	0.32	0.24	0.37
LRQ	0.10	0.30	0.30	0.19	0.15	0.02	0.21	0.27	0.25

2.3 Noise metrics estimation method

The noise metrics are calculated on the basis of the growth in operations, the rate of penetration into the fleet of aircraft generations G1 and G2, and the noise levels of individual aircraft of generations G0, G1 and G2.

The current aircraft fleet in service in the UK and the noise levels in EPNdB for each individual aircraft at each certification point (L_{G0}) was obtained from [7]. The set of individual aircraft were classified into the 4 aircraft categories as indicated in Section 2.1. For each of the four aircraft categories considered and for each certification point, a 'representative' noise level in EPNdB for generations G1 and G2 (L_{G1} and L_{G2}) was estimated as indicated in Section 2.2. For the calculation of the L_{Aeq} and NNI type metric (hereafter defined as L_{kAeq}), L_{Amax} and SEL descriptors were required. Thus, for each certification point, L_{Amax} and SEL descriptors were estimated from a series of linear least square regression analyses for the set of current G0 aircraft using the noise level in EPNdB as dependent variable.

For each individual aircraft i within each aircraft generation, and for each certification point, let us define

$$L_{T,i} = 10 \cdot \log_{10}\left(\left(\frac{1}{T}\right) \cdot 10^{\left(SEL_i/10\right)}\right) \quad (2)$$

with $T = 60 \cdot 60 \cdot 16 = 57600$ s

$$L_{T,av} = 10 \cdot \log_{10}\left[\left(\frac{1}{\sum_i^n N_{G0,i} + \sum_i^n N_{G1,i} + \sum_i^n N_{G2,i}}\right) \cdot \left(\sum_i^n N_{G0,i} \cdot 10^{\left(L_{TG0,i}/10\right)} + \sum_i^n N_{G1,i} \cdot 10^{\left(L_{TG1,i}/10\right)} + \sum_i^n N_{G2,i} \cdot 10^{\left(L_{TG2,i}/10\right)}\right)\right] \quad (3)$$

where $N_{G0,i}$, $N_{G1,i}$ and $N_{G2,i}$ are the number of movements for each individual aircraft i of generations G0, G1 and G2 respectively, and $L_{TG0,i}$, $L_{TG1,i}$ and $L_{TG2,i}$ are the sound levels for each individual aircraft i of generations G0, G1 and G2 respectively.

$$L_{kAeq} = L_{T,av} + k \cdot \log_{10}\left(\sum_i^n N_{G0,i} + \sum_i^n N_{G1,i} + \sum_i^n N_{G2,i}\right) \quad (4)$$

For L_{Aeq} calculation $k = 10$. For L_{kAeq} calculation $k = 15$ and a cut-off of $L_{Amax} = 67$ dBA is set, so only events with L_{Amax} above 67 dBA are considered.

The estimation of noise contour areas were performed using RANE, a model under development in ISVR. In its current version, RANE is able to estimate changes in noise contour areas as accurately as FAA Integrated Noise Model (INM) [10]. To estimate noise contour areas, for each individual aircraft, the number of movements ($N_{G0,i}$, $N_{G1,i}$ and $N_{G2,i}$), and the operational profiles and the Noise-Power-Distance curves (NPDs) for departure and approach operations were required. For generation G0, the operational profiles and the NPDs were obtained from the Aircraft Noise and Performance (ANP) database. For each aircraft category of generations G1 and G2 the same operational profiles as the reference G0 aircraft (see Section 2.1) were used. Also, for each aircraft category of generations G1 and G2, the NPDs were derived from the NPDs of the corresponding reference G0 aircraft corrected with the noise reductions $L_{TG1,i} - L_{TG0,i}$ and $L_{TG2,i} - L_{TG0,i}$ respectively. For approach NPDs the noise reductions at approach certification point were used. Regarding departure NPDs, for power settings above and below the power cut-off value the noise reductions at lateral and flyover certification points were used respectively.

3. Results

3.1 57-dBA L_{Aeq} contour area estimation

Fig. 1 shows the estimations of changes in the 57-dBA L_{Aeq} contour area, as compared to the 57-dBA L_{Aeq} contour area in the reference year 2010, for the DfT-Central aviation growth projection (left) and the ESRA NW projection (right). Solid black lines represent the scenario of only current types (plus the generation G1 of LRQ aircraft that entered into service in 2007), the coloured lines represent the five noise reduction due to technology scenarios.

Without the introduction of noise reduction technology, by 2050, the 57-dBA L_{Aeq} contour area will increase by 34% (DfT-Central aviation growth projection) and 22% (ESRA NW aviation growth projection). As mentioned above, although with the ESRA NW projection the aviation growth for short-haul aircraft (RJ and SMRT) is 3 times lower than the one for long-haul aircraft, only an increase in the overall fleet movements of 44% is estimated (89% for DfT-Central). Moreover, in Fig. 1 it is observed that in 2025 (EIS date for the generation G2 SMRT aircraft) a step-change will take place in the change of noise contour area for the noise reduction scenarios, with the exception of the Ultra-Low-CO2 scenario that assumes no noise reduction for short-haul aircraft. It should be noted that the SMRT aircraft category is the dominant category in terms of movements in the UK. From these results it can be deduced that, regardless of the scenario considered, the main driver in the change of noise contour areas is the short-haul aircraft category.

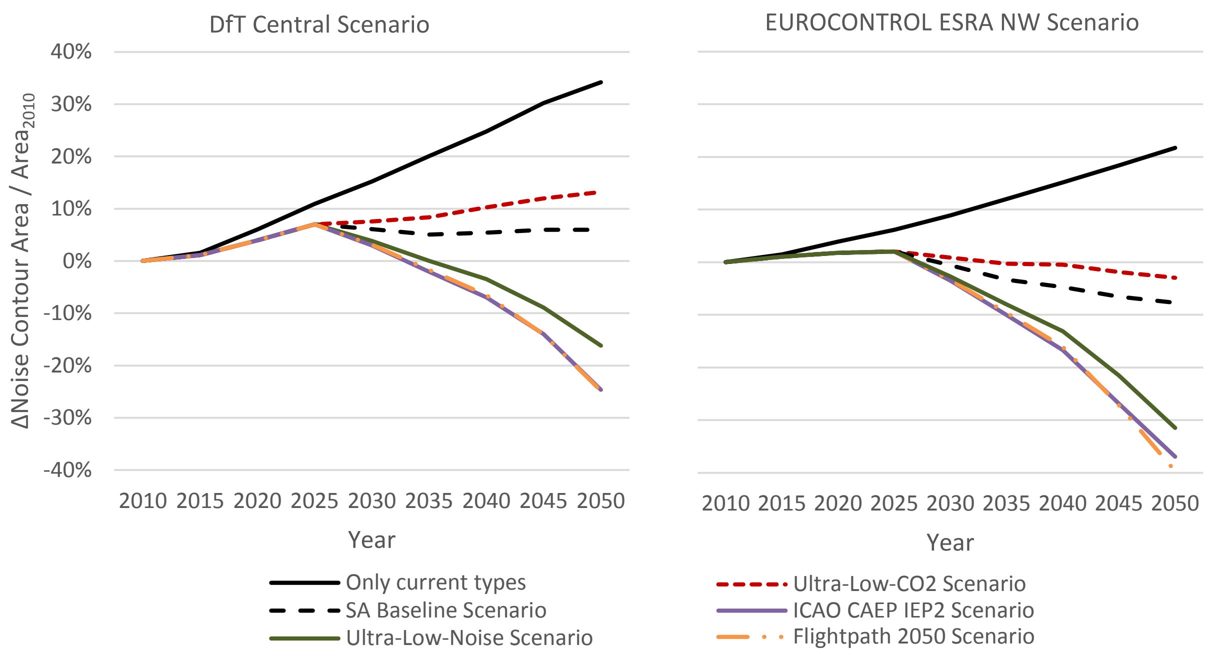

Figure 1: Changes (relative to year 2010) in the 57-dBA L_{Aeq} contour area for the DfT-Central aviation growth projection (left) and the ESRA NW projection (right). Note that solid black lines represent the scenario of only current types (plus the generation G1 of LRQ aircraft that entered into service in 2007) and the coloured lines represent the five noise reduction due to technology scenarios.

Considering the introduction of novel quieter aircraft, the relative change in 57-dBA L_{Aeq} contour area by 2050 significantly differs depending on the noise reduction scenario considered: from +13% (Ultra-Low-CO2) to -25% (ICAO CAEP IEP2 and Flightpath 2050) with DfT-Central projection (left); and from -3% (Ultra-Low-CO2) to -40% (ICAO CAEP IEP2 and Flightpath 2050) with ESRA NW projection (right). Also, Fig. 1 shows that both the novel aircraft-noise technology vision (ICAO CAEP IEP2) and Flightpath 2050 vision will reach similar values in noise contour areas reduction. Finally, notwithstanding, among others, the differences in methodology, fleet composition and transition from current to future aircraft types, the results for SA Baseline and Ultra-Low-Noise scenarios in the UK seem to be in line with the recent estimation conducted for the whole European Aviation sector [11].

3.2 L_{Aeq} and NNI estimation at each certification point

Fig. 2 shows the changes in sound-level (as compared to year 2010) for each noise reduction scenario at lateral (top), flyover (middle) and approach (bottom) certification points. Left plots present L_{Aeq} values and right plots show L_{kAeq} values (i.e. k = 15 and only events above L_{Amax} = 67 dBA considered). The aviation growth projection used is DfT-Central.

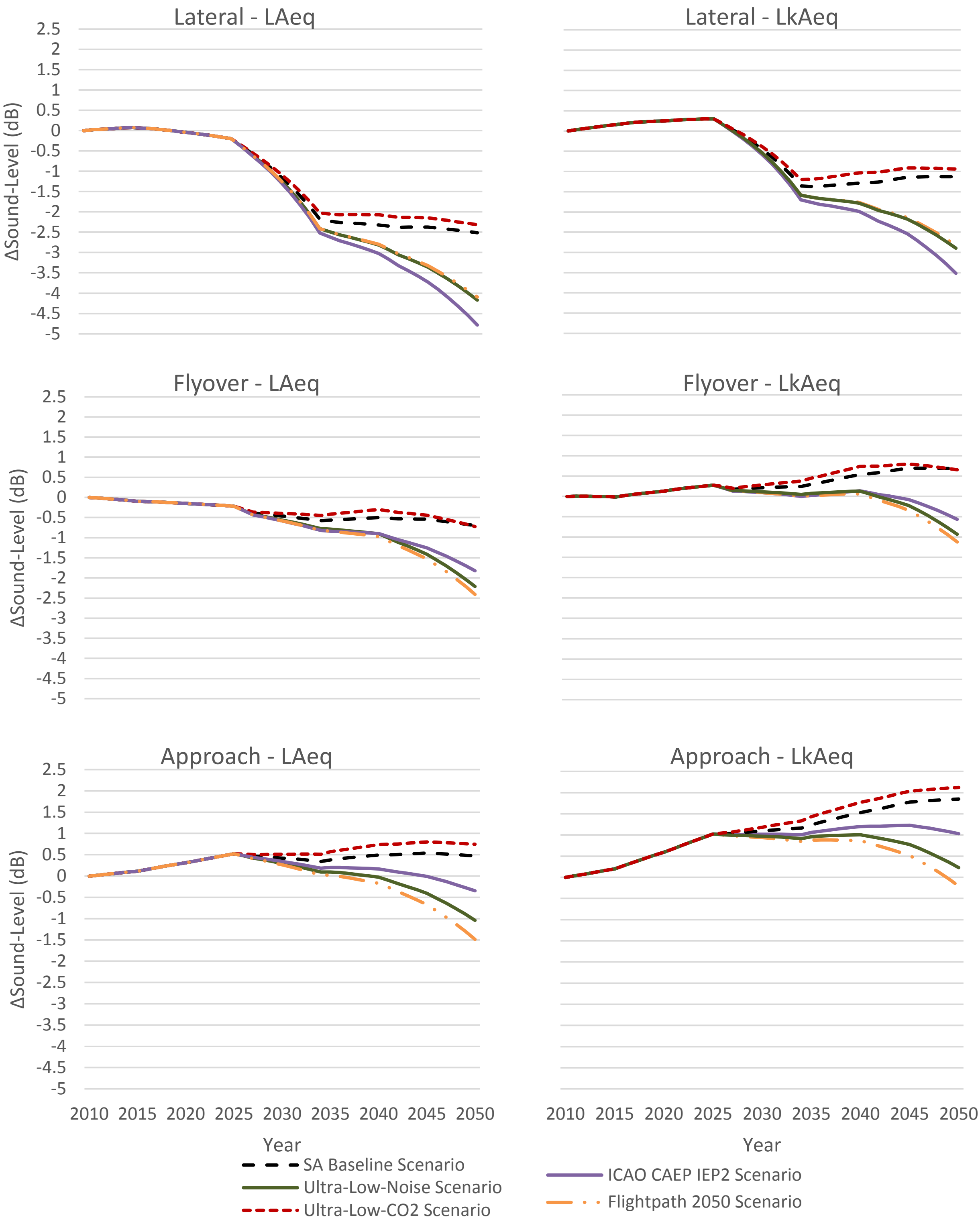

Figure 2: Changes in sound-level (as compared to year 2010) for each noise reduction scenario at lateral (top), flyover (middle) and approach (bottom) certification points (with DfT-Central aviation growth). Note that left and right plots present L_{Aeq} and L_{kAeq} values respectively.

As observed in Fig. 2 (top), the highest reduction in sound-level, as projected by all the noise reduction scenarios considered, will take place at the lateral certification point. At early stages in departure operations (at maximum power) jet noise is the dominant individual noise source [8]. As one of the main factors for the development of noise reduction technologies, the increase in bypass ratio (BPR) allows significant reductions in jet noise. At flyover (after power cut-off) and approach certification points jet noise is much less influential, and other individual sources (mainly fan and airframe) have important contributions. From the results showed in Fig. 2 (flyover - middle and approach - bottom) it can be assumed that the technologies for reducing noise in other individual sources do not seem to be as efficient as jet noise reduction technologies for offsetting the significant increase in number of aircraft movements. Regarding approach operations, with airframe having a significant contribution in the noise emitted, novel non-conventional aircraft architectures might be required for reducing noise at the same extent as in departure operations.

With the penalty assigned to the number of events (k = 15 in L_{kAeq}), the effect of the noise reduction as projected by the different scenarios for offsetting the increase in air traffic growth is significantly lessen (Fig. 2 – right). This is especially apparent for the approach certification point, where an increase in sound-level is found with all the technology scenarios considered.

Although with ICAO CAEP IEP2 and Flightpath 2050 scenarios similar reductions in 57-dBA L_{Aeq} contour area are found, in Fig. 2 it is observed that the noise reduction achieved at each certification point with each of these scenarios differs significantly. Thus, while at the lateral point the highest noise reduction is achieved with the ICAO CAEP IEP2 scenario, at flyover and approach points the with the ICAO CAEP IEP2 scenario is not achieved as much noise reduction as with the Flightpath 2050 scenario. Recalling that the ICAO CAEP IEP2 represents the vision of the industry, and therefore, the most likely scenario, the contribution of departure and approach operations to the total L_{Aeq} (with this scenario) is estimated (Fig. 3). Assuming that the contribution of departure operations is $\frac{10^{\left(\left(\left(L_{Aeq,lat}+L_{Aeq,fly}\right)/2\right)/_{10}\right)}}{10^{\left(L_{Aeq}/10\right)}}$ and of approach operations is $\frac{10^{\left(\left(L_{Aeq,app}-9\right)/10\right)}}{10^{\left(L_{Aeq}/10\right)}}$ (with $L_{Aeq,lat}$, $L_{Aeq,fly}$ and $L_{Aeq,app}$ as the L_{Aeq} at lateral, flyover and approach points), it is found that by 2050 the departure and approach operations will have an equivalent contribution to the total L_{Aeq} emitted.

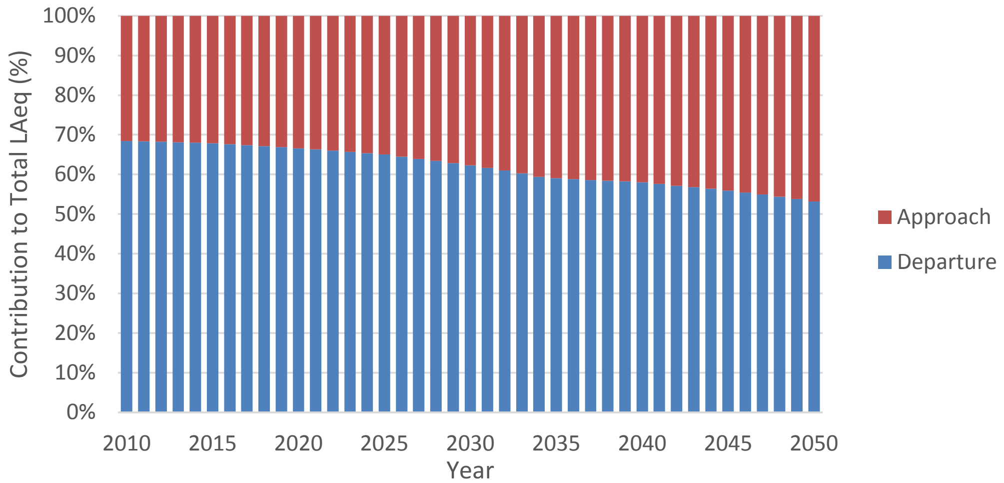

Figure 3: Contribution of departure and approach operations to the total L_{Aeq} emitted.

4. Conclusions

In light of the results presented in this paper, the 57-dBA L_{Aeq} contour area might range by 2050 between +13% and -40% (as compared to year 2010) depending on the aviation growth projection and the noise reduction (due to technology improvements) scenario considered. If no replacement with future quieter aircraft is assumed, and therefore only current types are in service, by 2050 the 57-dBA L_{Aeq} contour area might range between +44% (DfT-Central projection) and +22% (ESRA NW projection). It should be noted that, notwithstanding differences in methodology, fleet composition and transition from current to future types, the estimation presented here for the UK is in line with the recent estimation conducted for the European aviation sector.

Although with the ICAO CAEP IEP2 and Flightpath 2050 scenarios similar reductions in noise contour areas are estimated, the vision of the industry (ICAO CAEP IEP2) assumes that the highest reduction will take place at the early stages of departure operations (lateral certification point). As consequence of this, with ICAO CAEP IEP2 scenario is estimated that by 2050 departure and approach operations will have an equivalent contribution to the total L_{Aeq} emitted. These results suggest that the -9dB correction applied to approach operations in order to make them comparable with departure operations might need to be at least revised.

Notwithstanding the replacement of current types with novel quieter aircraft, the significant increase in number of aircraft movements as projected, might have an important effect on the community noise annoyance near airports. For this reason, further work will be require in order to evaluate the penalty to be applied to the number of events in the calculation of noise exposure metrics, but also to quantify the noise reduction required to offset the increase in movements for reducing (or at least for avoiding a significant increase of) aviation noise annoyance in communities near airports.

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