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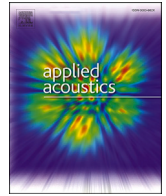
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Airport noise forecasting to 2050: Integrating the Blended Wing Body concept

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ABSTRACT

This paper presents a comprehensive noise mapping study for a Western European Airport in the year 2050, with a focus on incorporating the novel Blended Wing Body (BWB) aircraft. The BWB's noise data, simulated with CARMEN, and NPD data are generated to integrate the future aircraft concept into the conventional noise mapping software SoundPLAN. Subsequently, the BWB is integrated into the 2050 baseline scenario forecast, replacing wide body generation 2 aircraft, encompassing air traffic uptake, technology evolution, and fleet shifts. The results show 5% smaller $L_{den} = 45$ dB(A) and $L_{night} = 40$ dB(A) contour lines when the BWB generation 3 aircraft makes up 5% of the operations at Dublin Airport. From 2023 to 2050 air traffic is expected to increase around 47%. This forecast shows an increase of around 25% in L_{den} and 45% in L_{night} contour areas in the same time frame. Area and population exposure estimates are presented for 2050 and compared to 2023.

1. Introduction

The rise in air traffic will be linked to an increased impact of airport noise into the foreseeable future. This heightened noise exposure has been associated with sleep disturbances [1], heightened stress levels [2], and the potential development of cardiovascular and metabolic diseases [3,4]. Presently, noise poses an immediate health impact on exposed populations, rendering it a critically significant pollutant to mitigate, particularly in urban and densely populated areas [3,5].

Many aircraft have implemented noise reduction techniques for minimizing departure and arrival noise. Furthermore, modern aircraft, integrating the latest technological advancements, often exhibit significantly lower noise levels compared to their predecessors [6]. Forecasting airport noise proves instrumental in establishing optimal flight routes and procedures to accommodate the growing air traffic. Additionally, it aids in defining noise limit contour lines, thereby enabling adjustments in the planning and construction of urban agglomerations [7].

The airport noise forecast for Dublin Airport (Dublin, Republic of Ireland) in 2050 considers not only the anticipated increase in flight numbers at an Average Annual Growth Rate (AAGR) of 1.2% [8,9] but also incorporates advancements in aircraft technology up to 2050 and shifts in fleet shares [9,10]. As the trajectory of technology uptake and

noise optimization reaches a plateau, the aviation industry is exploring new frontiers with the development of innovative aircraft concepts for future operations. These concepts encompass not only electric propulsion [8,9] but also novel aircraft configurations like the Blended Wing Body (BWB) [11] and the braced wing aircraft [12] and highly fuel-efficient engine concepts such as the open rotor engine [13].

1.1. Aircraft noise emission

Environmental noise mapping involves the measurement or simulation of noise, analyzing noise levels in specific locations, and presenting the information on a map. This process includes identifying noise sources, displaying varied noise levels spatially, and assessing the noise source interactions to pinpoint highly affected areas. It plays a crucial role in planning, policy development, and implementing noise source restriction and optimization strategies for land use planning [7].

Environmental noise modeling encompasses road traffic, train, industrial, construction, and aircraft noise. This paper will focus on commercial aviation and therefore overall airport noise only. The European Environmental Noise Directive (END) mandates the preparation of strategic noise maps every five years, covering road traffic on major roads, railway traffic along major rail lines, aircraft noise for major

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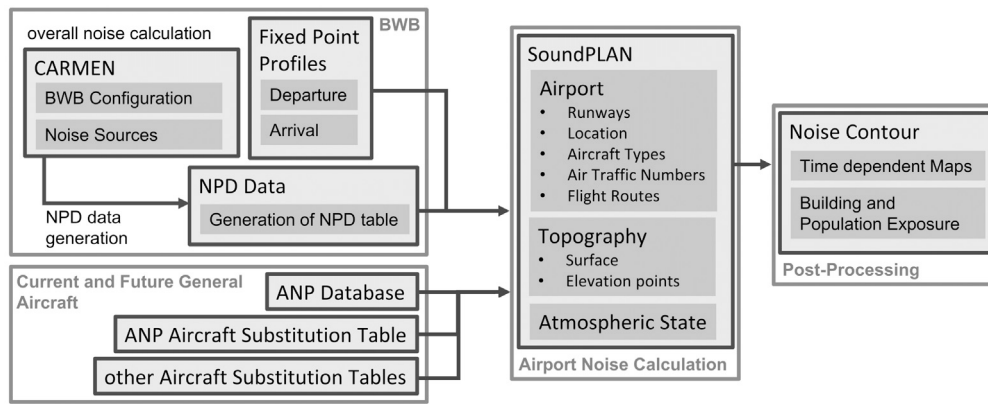


Fig. 1. Airport noise mapping procedure with future aircraft concepts.

airports, and industry noise maps [14]. In the Republic of Ireland the Environmental Protection Agency (EPA) has the responsibility to produce strategic noise maps that must include L_{den} and L_{night} with an evening penalty of 5 dB(A) and a nighttime penalty of 10 dB(A) (Equation (1)) [15,16].

The definition of airport noise limits remains ambiguous, with guidelines providing recommendations rather than enforceable noise limits. As a result, the interpretation and presentation of noise exposure vary across countries and airports [17]. In accordance with the Environmental Protection Agency NG4 guidelines [17] and utilizing the Common Noise Assessment Methods in Europe (CNOSSOS-EU) methodology [18], this paper will showcase the recommended noise level of $L_{den} = 45$ dB(A) and $L_{night} = 40$ dB(A) by the WHO [3].

$$L_{den} = 10 \log \frac{1}{24} \left(12 \cdot 10^{\frac{L_{day}}{10}} + 4 \cdot 10^{\frac{L_{evening}+5}{10}} + 8 \cdot 10^{\frac{L_{night}+10}{10}} \right) \quad (1)$$

2. Noise mapping procedure with future aircraft concepts

Fig. 1 displays the noise mapping procedure of this paper. The calculation of aircraft noise is based on Noise-Power-Distance (NPD) data (see Section 3.2). NPD data for current and future general aircraft is sourced from the Aircraft Noise and Performance (ANP) database and ANP aircraft substitution tables [19,20]. Aircraft types not referenced in the ANP aircraft substitution tables are obtained from the Civil Aviation Authority¹ [21] and the Dublin Airport Authority² [22]. Utilizing a proxy aircraft, the aircraft substitutions tables provide departure and arrival noise corrections, to simulate the characteristics of new aircraft models [20].

For generation 3 aircraft (future aircraft concepts), which are currently in the early stages of development [23], NPD data is generated with the help of CARMEN (Codes Acoustiques par Rayons pour la Modélisation et l'Estimation de Nuisances) developed at ONERA (see Section 3.1). For this present study, a Blended Wing Body (BWB) was chosen as a representative candidate for 2050 generation 3 aircraft concepts. Its NPD data and departure and arrival profiles are combined in the noise mapping software SoundPLAN (Section 3.2).

The SoundPLAN model incorporates airport-specific details and the topography in the calculation area and employs the ECAC Doc 29 4th Edition as the standard for aircraft noise calculation. SoundPLAN offers the flexibility to expand its database to accommodate new aircraft, making it a suitable tool for assessing the noise impact of emerging aviation

¹ Aircraft substitution data for future aircraft and modernized generation 2 aircraft: Boeing 737maxG2 variations, Boeing 787G2 variations, A320neoG2 family variations, A350G2 variations, and E170/190G2.

² Aircraft substitution data for A330-900neo, A350-900, Boeing 777X, and E190-E2.

technologies. Post-processing of the noise data is conducted in QGIS, where building and population data are combined.

In the modeling procedure for 2050 flight numbers are calculated for a baseline scenario in air traffic and technology uptake. In addition, the fleet share and generation share are adjusted for 2050 (see Section 4). For population and area exposure comparison, the overall airport noise for 2023 is also calculated.

All SoundPLAN calculations were conducted on an *Alienware Aurora R12* computer, equipped with an *11th Gen Intel(R) Core(TM) i9-11900KF* processor running at a base frequency of 3.50 GHz, with 8 cores and 16 logical processors. The calculations took around 17 days each. Elevation data from *Open Street Map* [24] was utilized for the SoundPLAN model.

3. Future aircraft concept (BWB)

Future aircraft concepts, designated as generation 3 aircraft, mark a pivotal evolution in aviation. Novel aircraft types are currently undergoing the early stages of concept development, while generation 2 aircraft are expected to discontinue around 2050 [23]. Among these visionary concepts, generation 3 aircraft encompass a spectrum of innovations, from alternative propulsion methods such as electric propulsion [25] or open-rotor engines [13] to groundbreaking airframe designs like Blended Wing Body (BWB) [26], braced wing, or box wing configurations [12].

In this study, the BWB aircraft concept serves as an archetype representative of the collective vision for generation 3 aircraft in the year 2050. Using ONERA's noise prediction software CARMEN, a BWB aircraft departure and arrival profile was generated in the form of Noise-Power-Distance (NPD) data and included in the noise forecast for 2050 for Dublin Airport.

3.1. Aircraft noise source modeling

For new aircraft concepts with futuristic designs such as a Blended Wing Body, no real-world data yet exists. For these cases, usually one turns to parametric tools, used in the concept stage of aircraft development. In this study, the ONERA in-house system noise prediction tool CARMEN was used to calculate all configurations that were necessary for the NPD data generation, as described in Section 3.2.

CARMEN is a parametric tool, consisting of three modules: the calculation of noise sources, their installation, and their propagation towards the ground. It was validated on classical tube and wing aircraft [27] and is now mainly used for concept stage evaluations of new aircraft architectures, or, more recently, drone fleet impact evaluation.

The work presented in this paper is based on the Blended Wing Body concept developed by Roma Tre University (Fig. 2, BOLT aircraft) in the framework of the Horizon 2020 research project ARTEM (Aircraft Noise Reduction Technologies and related Environmental iMPact, Grant Agreement 769359) [28]. For this study, an optimized layout featuring



Fig. 2. Roma Tre University Blended Wing Body concept BOLT developed in H2020 ARTEM project (Grant Agreement 769359).

two turbofan engines with a Bypass Ratio (BPR) of 12 and a fan diameter of 3.75 m is employed. Technical details on the aircraft itself can be found in [11,29,30].

In CARMEN, all major noise sources are calculated with semi-empirical or analytical noise models at discretized time steps all along the trajectory, providing directivity and noise spectra in the far field. For this study, the main noise sources of a BWB are considered, which are jet, fan, landing gear and flap noise.

As is to be expected, the main feature of a flying wing in terms of outdoor acoustics is the usage of the fuselage as a masking obstacle to the noise sources radiating towards the ground. Indeed, when putting the engines on top of the fuselage, one might expect important noise reduction below the aircraft. The installation effects calculation is, hence, an important step in the noise assessment methodology. As presented in [11], for the low-frequency range, an ONERA in-house boundary element method tool (BEMUSE) is used to calculate masking, reflection, and diffraction due to the fuselage. Above 1 kHz a simplified integral method, relying on the Kirchhoff approximation [31] and the Maggi-Rubinowicz formulation of the Kirchhoff diffraction theory [32] is used. Finally, the sound is propagated by ray tracing toward receivers on the ground, taking into account the Doppler effect, atmospheric absorption, and geometrical spreading. While it is possible to include meteorological phenomena, in this work, where NPD data have to be generated, a standard atmosphere is considered, as specified in SAE-AIR-1845: Sea level pressure of 101.325 kPa, ambient temperature of 77°F, relative Humidity of 70 % and zero wind.

All input data that were necessary to the calculation of the noise contours presented in 3.5 were taken from the ARTEM study [11]. In the framework of that project, several aircraft configurations had been tested for departure and landing. The flight simulation environment within the FRIDA software of Roma Tre University [33] was used to estimate realistic trajectory profiles and associated target engine parameters. Those served as input to RWTH's software GasTurb [34,35] that generated the input data necessary to the noise source models, for two turbofan engines of a bypass ratio of respectively 8 and 12, that were compared in the framework of ARTEM. In addition, a set of noise reduction technologies, that were evaluated by ARTEM partners, was introduced and applied in the form of delta noise levels to the major noise sources present on the aircraft. The engines are, hence, equipped with fan inlet and outlet linings, and jet porous material. To address airframe noise, a combination of main landing gear noise reduction and a new trailing edge technology is implemented. More details on the latter and the engine parameters can be found in [11,30].

Fig. 3 shows an example for a noise emission sphere for one thrust-altitude configuration, with and without installation effects by the aircraft fuselage. One can appreciate the important masking effects, especially for the fan inlet noise, and hence to the front of the aircraft.

The efficiency of the masking effect due to the engines' location on top of the fuselage, combined with new generation turbofan engines and the set of noise reduction technologies was evaluated and led to very interesting possible noise reductions at certification points. The quietest option (with the turbofan engine of bypass ratio 12 and the complete set of noise reduction technologies) is estimated to reduce L_{Amax} values at

the flyover certification point by more than 10 dB, by means of a CARMEN calculation. This version was chosen to be the one implemented into SoundPLAN.

3.2. Generation of Noise-Power-Distance (NPD) data

The Noise-Power-Distance (NPD) data is generated through a simulation involving the BWB aircraft, flown at predefined heights (60.96 m, 121.92 m, 192.02 m, 304.8 m, 609.6 m, 1219.2 m, 1920.24 m, 3048 m, 4876.8 m, 7620 m) under various power settings (Fig. 4). Net corrected thrust was used. During the simulation, a simulated microphone at a height of 1.2 m records noise levels at 0.5-second intervals over a 60 or 120-second duration (depending on the considered flight height, in order to ensure enough data for EPNL calculation). Direct propagation was considered and an approximated correction of + 3 dB was applied to sound pressure level to take into account ground reflections.

Following this, SEL, L_{Amax} , PNLTM, and EPNL, as per calculation procedure outlined in the documentation ICAO [7], are computed. Subsequently, tables are generated for each power setting at different heights, presenting the computed values for the four distinct noise metrics.

The calculation procedure for the Sound Exposure Level (SEL) involves augmenting the Sound Pressure Level (SPL) with an A-weighting factor on a per-frequency and per-timestep basis. Subsequently, the overall SPL is computed for each timestep, and the cumulative result is obtained across all timesteps. In the context of aircraft noise L_{Amax} represents the maximum of the A-frequency-weighted S-time-weighted sound level during the run [7].

The instantaneous Perceived Noise Level (PNL) denoted as $PNL(k)$ is computed by converting the SPL in each one-third octave band i spanning 50 Hz to 10000 Hz to perceived noisiness $n(i, k)$ using the Noy table given in ICAO [7]. Afterwards, the noisiness values are combined by equation (2) and the PNL values determined by using equation (3).

$$N(k) = 0.85 n(k) + 0.15 \sum_{i=1}^{24} n(i, k) \quad (2)$$

$$PNL(k) = 40.0 + \frac{10}{\log 2} \log N(k) \quad (3)$$

A tone correction factor $C(k)$ is added to Perceived Noise Level (PNL) to capture the annoyance of tones. The maximum Tone Corrected Perceived Noise Level (PNLT), denoted as $PNLTM$ is then determined from the instantaneous values. In order to determine the Effective Perceived Noise Level (EPNL), a duration penalty in form of a duration correction factor D , is calculated according to ICAO [7] and applied.

3.3. Airplane data for ECAC library used in SoundPLAN

The profiles of the Blended Wing Body aircraft are incorporated as fixed-point departure and arrival profiles in SoundPLAN and were generated by University Roma Tre [33]. The lateral directivity identifier accounts for engine installation effects and can be set to fuselage-mounted or underwing-mounted engines [36]. For the BWB aircraft it is set to underwing-mounted engines *wing*, since shielding effects are already factored into the overall noise source computation [11]. The spectral class for departure is designated as 105, while for arrival, it is set to 205. SoundPLAN uses imperial units for aircraft-specific data. The maximum take-off distance is set to 4450 ft, MTOW to 491 630 lb, and maximum thrust is set to 96 667 lb (input from the RWTH engine database generated in the framework of the ARTEM project [28,35]).

3.4. Limits to the approach

The simulation of the BWB aircraft in this study is subject to several limitations that warrant consideration. The departure and arrival profiles utilized in the simulation are limited in their scope and may not

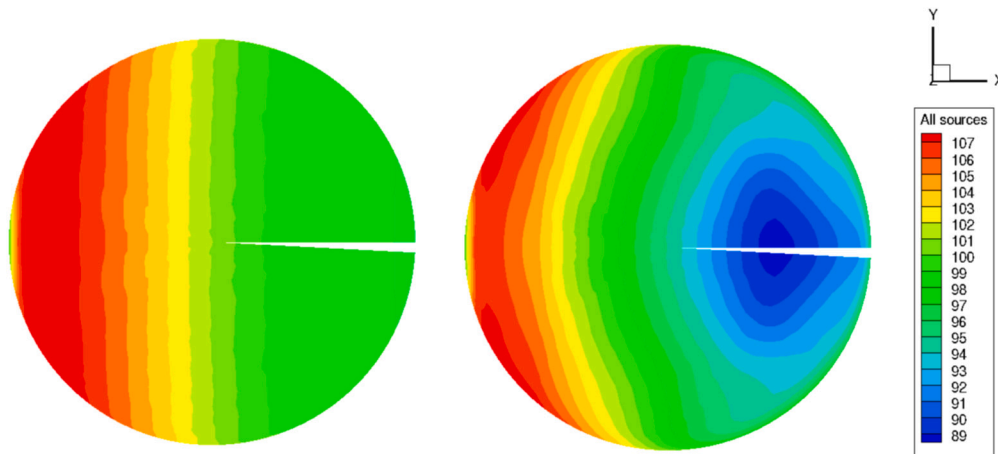


Fig. 3. View below of noise emission sphere without (left) and with (right) shielding effects. Flight direction in the positive x-direction. Configuration 860000 lb, 122 m.

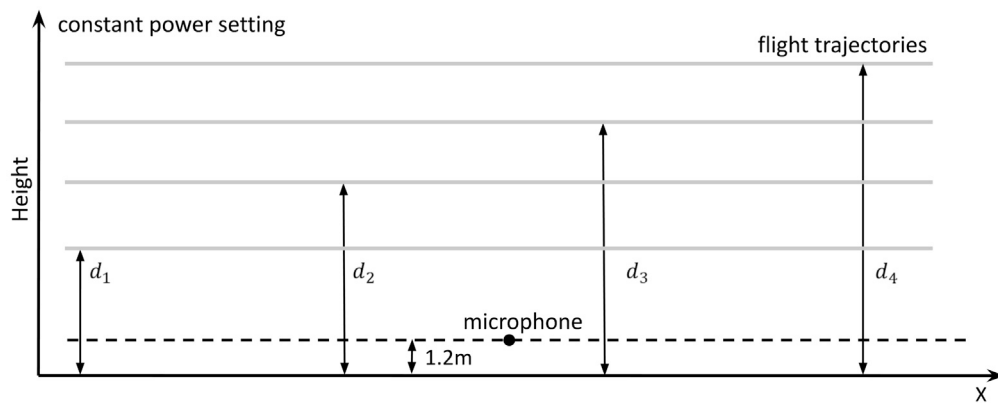


Fig. 4. Noise-Power-Distance (NPD) Data generation for simulated aircraft - flight repeated for different heights (flight trajectories) and different power settings.

fully capture the variability present in actual flight operations. Other assumptions, such as spectral class and directivity identifier, as well as the consideration of only one departure and arrival profile, further contribute to the limitations of this approach. It is crucial to acknowledge that the simulation of the BWB aircraft is based on theoretical models and assumptions, lacking real-life data validation.

3.5. Departure noise comparison with other aircraft

Departure and arrival procedures and therefore departure and arrival profiles are aircraft, aircraft weight, and airport dependent. For aircraft noise models departure profiles are segmented into a take-off segment, and a combination of climb³ and acceleration⁴ segments up to around 3000 m. Each aircraft has its individual departure and arrival profiles. In general, it can be said that a steeper climb profile can lead to a shorter but wider noise contour, while shallow climbs prolong the noise contour lines along the ground track [36].

Fig. 5 shows the departure noise contour lines of different wide body aircraft at $L_{Amax} = 55$ dB(A) available in the ANP database in comparison to the BWB aircraft. Depending on the departure profile, the L_{Amax} footprint can increase by around 30 % for these wide body aircraft. The generated BWB noise contour is around 55 % smaller than the B777X and the B788 aircraft. Simultaneously, the BWB is projected to be approximately 25% lighter than the B777X, yet it maintains a range just over 10000 km, which falls within a range of 3000 km to 6000 km lower

Table 1

Generation 2 and 3 wide body aircraft comparison (with Boeing aircraft [37] and BWB aircraft [11,28,35]).

Aircraft	Generation	MTOW [lb]	Passenger Capacity	Range [km]	Area [km^2] $L_{Amax} = 55$ dB
B777X	2	660000	395	16190	126.40
B788	2	502500	248	13530	125.55
B77W	2	775000	392	13649	211.77
BWB	3	491630	400	10186	56.41

than the compared wide body aircraft listed in Table 1. The anticipated generation 3 wide body aircraft is expected to accommodate 400 passengers, a capacity comparable to that of the B77W and B777X. The smaller departure footprint of the BWB aircraft shows that future aircraft concepts have the capability to significantly impact overall airport noise.

4. Technology uptake 2050

Aircraft are classified into generations and types based on their production year and aircraft size. Eurocontrol [8] and Mott MacDonald Global Aviation [23] categorize aircraft according to their size and passenger capacity, distinguishing between narrow-body, wide-body, regional jet, and turboprop aircraft, which is important in the context of fleet distribution. Aircraft typically have an anticipated lifespan of approximately 25 years in the aircraft fleet, after which they may continue in service through conversion into freighters [23].

Aircraft generations indicate the technology development and production year and cycle of an aircraft. By 2050 generation 0 aircraft will

³ Endpoint is defined through altitude.

⁴ Endpoint is defined through calibrated airspeed and climb rate.

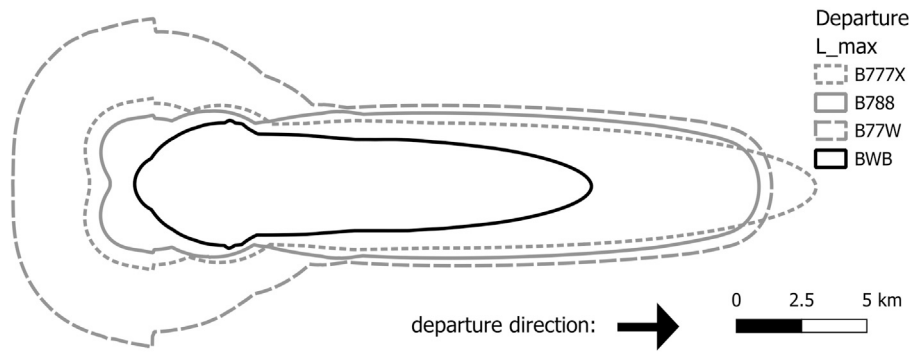


Fig. 5. Aircraft departure noise footprint contour lines at $L_{max} = 55$ dB(A) for different wide body aircraft (generation 2 and generation 3).

Table 2
Air traffic operation at Dublin Airport for 2050 for the base air traffic increase scenario based on projections for 2025 from Dublin Airport [41].

Operation	North Runway				South Runway			
	departure		arrival		departure		arrival	
time	day	night	day	night	day	night	day	night
movements	29906	5466	106394	1739	107822	12360	24440	22422
total	35371		108133		120182		46862	

be retired and the number of generation 1 aircraft (developed and produced in the 1990s or 2000s) will have significantly decreased [23,9]. The newest aircraft in 2023 is generation 2 aircraft, which are currently under development or just entering production, while generation 3 aircraft are future concepts, such as the BWB, braced wing or open-rotor aircraft and electric propulsion concepts [8,25,13,26,12].

Eurocontrol [9] predicts a share of 89 % generation 2 aircraft, 4 % conventional aircraft (generation 1) and 8 % revolutionary aircraft concepts in 2050. In addition, there is a high opportunity for short-distance flight replacements with rail, which would increase the percentage of long-distance flights [38].

4.1. 2050 fleet and aircraft generation share

For the purpose of this study an Average Annual Growth Rate (AAGR) of $AAGR = 1.2\%$ was utilized [9]. This growth rate represents the average baseline projection for the anticipated increase in air traffic within the Republic of Ireland. Notably, alternative scenarios can be considered with $AAGR = 0.6\%$ representing a slower rate of air traffic growth, and $AAGR = 1.8\%$ for a higher rate of increase. The calculations are based on tracked flight numbers obtained from Steve Beaney [39] for 2023. A detailed calculation procedure can be found in Einicke and Kennedy [40]. Under the base traffic increase scenario, the corresponding flight estimates stand at 244 635 for the year 2030, 275 628 for 2040, and 310 548 for 2050 [40]. Runway operation is calculated according the anticipated movement numbers from the North Runway Report [41] and can be seen in Table 2. These projections serve as valuable benchmarks for assessing the potential impacts and challenges associated with varying levels of air traffic growth in the specified timeframe.

In addition to examining air traffic growth, the analysis must also consider the progression of technology within the aviation sector. The classification of aircraft is contingent on both technological advancements and production generations [23]. A detailed analysis of 2030 and 2040 forecasts with different technology uptake scenarios was undertaken in Einicke and Kennedy [40]. The aircraft technology uptake and air traffic increase fleet and generation shares for 2030 and 2040 can be seen in Fig. 6.

The base of the aircraft fleet share shift is annual flight numbers from 2023. During this period, Dublin Airport witnessed an average opera-

tion of approximately 76 % narrow-body aircraft, with 9 % designated as wide-body, 7 % as regional jets, and 8.5 % as turboprop aircraft. In terms of generational classification, roughly 38.5 % of the aircraft operating from Dublin Airport were categorized as generation 0, followed by 41 % as generation 1, and 20 % as generation 2 aircraft. These baseline figures serve as the foundation for the subsequent analysis and projections in understanding the evolving landscape of Dublin Airport’s aircraft fleet composition.

In 2030, generation 0 aircraft are projected to constitute 18.88 % of the fleet, followed by generation 1 at 41.9 % and generation 2 at 39.0 %. Notably, the forecast for 2040 indicates a significant reduction in generation 0 to 11.2 %, accompanied by a rise in generation 1 to 28.7 % and a substantial increase in generation 2 to 60.1 %.

The forecasted evolution of the aircraft fleet at Dublin Airport for 2050, presented in Table 3, outlines the anticipated distribution of different aircraft generations in 2050 with future aircraft concepts, such as the BWB. Eurocontrol [9] anticipates that around 90 % of the aircraft fleet in 2050 will consist of generation 2 aircraft, with turboprop and regional aircraft types experiencing a continuous decline in fleet shares [8]. In addition, only 4 % of aircraft are anticipated to be conventional aircraft (generation 0 and 1), while up to 8 % are anticipated to be future aircraft concepts [9,38]. This forecast scenario is considered to be ambitious. In this study a baseline technology uptake scenario and baseline air traffic projections for 2050 are generated and it is assumed that Dublin Airport will operate a share of around 5 % future aircraft concepts.

The most intriguing aspect of this forecast is the introduction of a futuristic generation 3 aircraft, comprising 5.0 % of the fleet in 2050 with future aircraft concepts. This is particularly noteworthy, as it reflects the integration of innovative aircraft concepts, such as the BWB, showcasing a potential paradigm shift in aviation technology. Furthermore, it is anticipated that generation 0 aircraft will be phased out and not in service at Dublin Airport by the year 2050. The proportion of generation 1 aircraft is projected to decrease to 12.1 %, leaving the predominant share of the fleet composed of generation 2 aircraft at 83.0 %. This shift underscores the airport’s trajectory towards a more technologically advanced and environmentally conscious fleet composition, aligning with industry trends and the adoption of innovative aviation technologies. The first future aircraft concepts, such as electric or hybrid electric aircraft are anticipated between 2035 and 2040, while large future aircraft

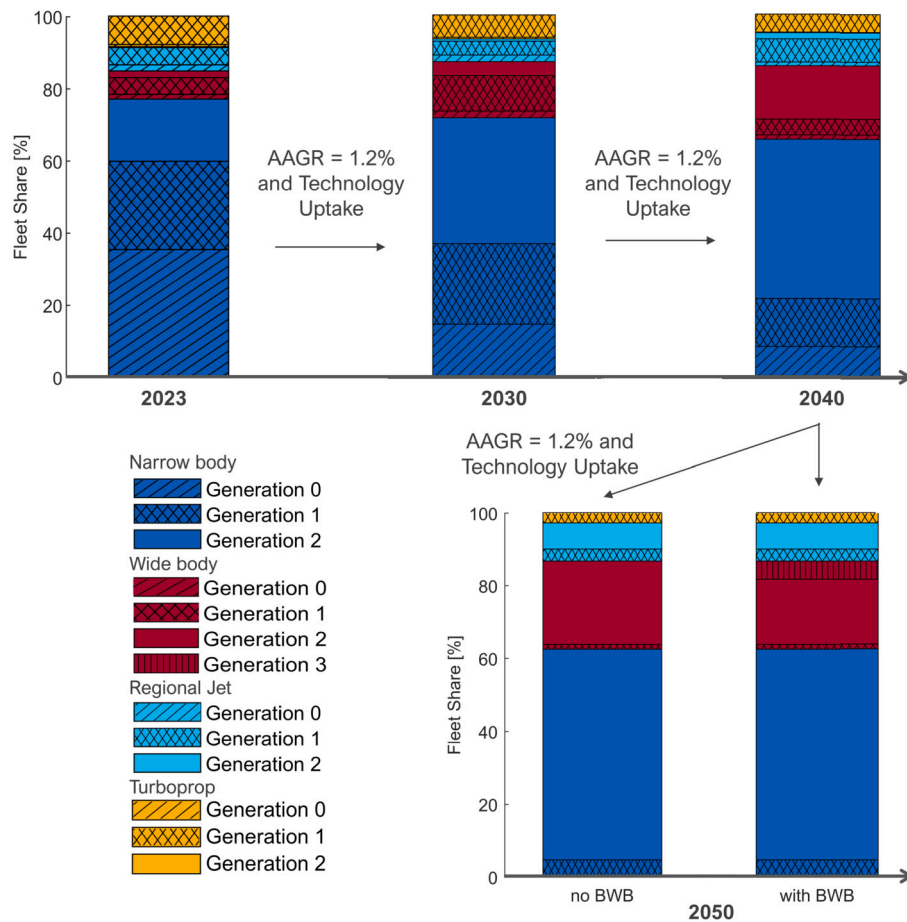


Fig. 6. Aircraft fleet and generation share at Dublin Airport for 2023 - 2050.

Table 3
2050 Dublin Airport fleet share forecast with future aircraft concept.

Fleet	Narrow body	Wide body	Regional jet	Turboprop	Total
generation 0 [%]	0.00	0.00	0.00	0.00	0.00
generation 1 [%]	4.72	1.30	3.40	2.68	12.09
generation 2 [%]	57.92	17.84	7.20	-	82.96
generation 3 [%]	-	4.96	-	-	4.96
total [%]	62.63	24.09	10.60	2.68	100.00

concepts, such as the BWB concept are expected to start service between 2035 and 2045 [9]. While certification for very small electric aircraft is already underway [42], wide body aircraft like the BWB are still in the developmental stages. In this study, it is projected that BWB aircraft will not be operational until 2050.

To assess the specific influence of generation 3 aircraft on the 2050 forecast for Dublin Airport’s aircraft fleet, an alternate scenario is examined by excluding any potential contributions from alternative future aircraft concepts. In this comparative analysis, the around 5 % representation of generation 3 aircraft within the wide body fleet is uniformly redistributed among the existing generation 2 wide body aircraft. Consequently, this redistribution elevates the overall share of generation 2 wide body aircraft to 22.8 %, while maintaining a consistent proportion within the wide-body fleet as a whole. This approach allows for a clearer understanding of the distinct impact that generation 3 aircraft introduces to the 2050 fleet composition at Dublin Airport.

Runway usage, daytime and nighttime operation and flight routes are modeled according to Dublin Airport [41]. As the air traffic numbers

increase by around 50 % in comparison to 2023 by 2050, the nighttime flights in this scenario increase to 115.

It’s crucial to acknowledge that the assumptions and estimations made for the year 2050 are subject to potential changes over time. Factors such as economic fluctuations, advancements in aircraft technology, and shifts in traffic patterns could significantly impact the outcomes. Therefore, it’s essential to recognize the inherent uncertainty associated with projecting future scenarios and to remain cognizant of the dynamic nature of these variables.

4.2. 2050 area and population exposure

This study primarily focuses on assessing area exposure to airport noise, recognizing that the complexity and uncertainty in predicting population exposure for 2040 and 2050 are linked to challenges in forecasting building data. Accurate predictions rely heavily on factors such as land use changes, urban development, and construction activities, which are subject to dynamic and evolving scenarios. Without comprehensive forecasts for building data, the assessment of population exposure becomes inherently uncertain. Consequently, it is anticipated that the challenges associated with predicting future population exposure will persist, and the absence of building data forecasts could lead to an underestimation of the true impact. In the absence of specific projections, it is reasonable to expect an increase in population exposure, given the historical correlation between urban development and heightened noise levels around airports.

The L_{night} and L_{den} contour lines for 2023 and 2050 scenarios are shown in Fig. 7. Residential property data from 2023 [43] is combined with population data from 2022 [44] to estimate population exposure.

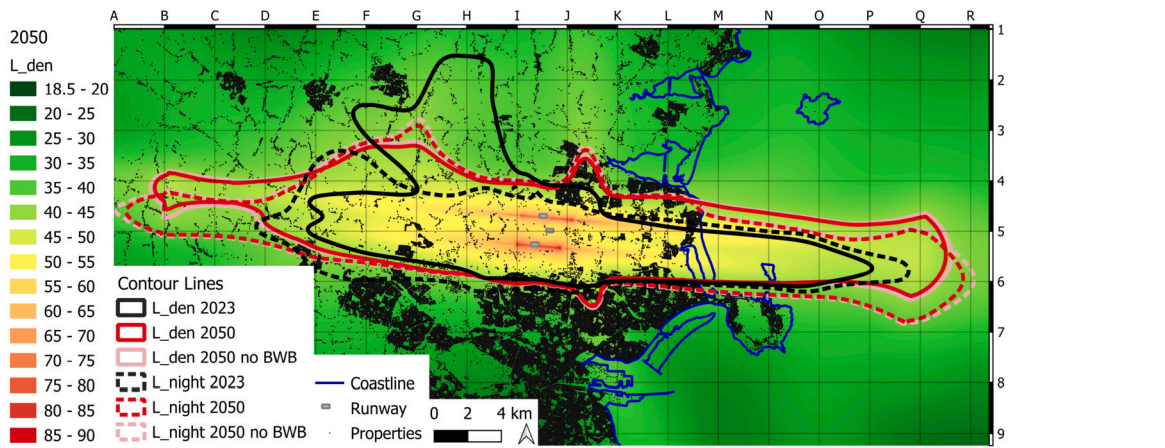


Fig. 7. 2050 noise map for different technology uptake scenarios with and without future aircraft concepts at Dublin Airport with L_{den} BTU noise footprint as background ($L_{night} = 40$ dB(A) and $L_{den} = 45$ dB(A)).

Table 4
2023 and 2050 area exposure at Dublin Airport.

Scenario	2023		2050		2050 no BWB	
	L_{night} [40 dB(A)]	L_{den} [45 dB(A)]	L_{night} [40 dB(A)]	L_{den} [45 dB(A)]	L_{night} [40 dB(A)]	L_{den} [45 dB(A)]
area [km^2]	165.66	171.48	239.61	214.10	252.29	226.01
houses	38083	30334	53032	44016	55987	46520
people	93352	77377	133847	109885	140721	116759

Scenario	2023		2050		2050 no BWB	
	L_{night} [50 dB(A)]	L_{den} [55 dB(A)]	L_{night} [50 dB(A)]	L_{den} [55 dB(A)]	L_{night} [50 dB(A)]	L_{den} [55 dB(A)]
area [km^2]	29.65	29.35	43.93	37.30	46.53	39.62
houses	2555	1296	3339	1800	4123	2151
people	6012	2771	9343	5303	10084	5218

Table 4 displays population and area exposure with and without future aircraft concepts in 2050, in addition to 2023 reference contour lines. In the particular scenario of Dublin Airport, the contour lines intersect with the Irish Sea, as depicted in Fig. 7 (M1:R9). This circumstance implies that up to 30 % of the noise contours are not pertinent to the surrounding population. However, this paper presents findings based on the complete contour analysis.

Air traffic is assumed to increase by around 47 % from 2023 to 2050. At the same time, the L_{den} contour line is projected to increase around 25 % to 2050 without BWB scenario. Comparing the 2050 with and without BWB aircraft contour lines reveals, that the L_{den} contour line can be decreased by around 5.3 % and the L_{night} contour line around 5.0 % when integrating the Blended Wing Body aircraft at a share of around 4.9 % into the fleet.

This disproportionate rise can be attributed to the substantial growth in generation 2 aircraft. Additionally, the introduction of BWB aircraft in 2050 contributes to the upswing in generation 3 aircraft. Moreover, the absence of generation 0 in the 2050 fleet share is anticipated, while the proportion of generation 1 is expected to decrease to below 15 %. These trends highlight the evolving aircraft fleet composition and underscore the significance of future aircraft concepts in shaping the aviation landscape.

The increasing flight numbers in 2050 induce notable changes in the shape of the noise contours for both day and nighttime operations. Given the preference for the North Runway during Western Operations [16], which account for approximately 70 % [41] of aircraft movements, the L_{den} contour line for 2050 extends westward by approximately 6 kilometers (Fig. 7, A:D4). Unlike in 2023, the right turn after departure from the North Runway to the west (Fig. 7, E:G3) is less pronounced in 2050, due to adjusted flight routes designed to circumvent populated areas.

This mitigation of the right turn is evident in both the night and daytime contour lines. While the L_{den} and L_{night} contour lines continue to expand eastward over the Irish Sea (Fig. 7, M4:R7) in 2050 due to increasing flight numbers, additional areas, and consequently populations, are expected to be exposed to aircraft noise to the northeast of Dublin Airport (Fig. 7, J:L4). Changes in aircraft routes also result in additional peaks to the north (Fig. 7, J3) and south (Fig. 7, J6) of the airport due to early turns from both runways. During nighttime operations, the South Runway becomes the preferred runway [41], leading to an extension of the L_{night} contour line to the southwest of the 2050 L_{den} contour line. Comparing the $L_{night} \geq 45$ dB(A) of 2023 and 2050, the area exposure increases around 45 % (with BWB) to 52 % (without BWB), attributed to the rise in nighttime flights from 65 to 115.

5. Conclusion

In this work the method of integrating new aircraft concepts into overall airport noise models was demonstrated. The overall noise emitted by a BWB aircraft was computed using CARMEN, and NPD data generated for analysis. Integrating the new aircraft concept into SoundPLAN, noise maps were generated combining current and future aircraft generations in the model. This study has produced noise maps depicting a potential air traffic scenario for Dublin Airport in 2050, incorporating a generation 3 aircraft concept. Specifically, a base air traffic increase at an AAGR of 1.2 % was computed and a fleet and generation shares calculated for the 2050 technology uptake of a Western European Airport. Population and area exposure were assessed and illustrated for noise levels exceeding $L_{night} \geq 40$ dB(A) and $L_{den} \geq 45$ dB(A).

A substantial increase in both area and population exposure in airport surrounding areas due to the air traffic escalation from 2023 to

2050 were revealed. It should be noted, that the population numbers from 2023 were utilized and not scaled up, therefore a stronger growth in population exposure in comparison to area exposure can be expected. Simultaneously, the incorporation of future aircraft concepts, such as the BWB, demonstrates its potential to mitigate the extent of airport noise contours during both day and night. Notably, air traffic rises by approximately 47% from 2023 to 2050, resulting in an increase of approximately 31% in L_{den} and 52% in L_{night} for the scenario without the BWB aircraft. Introducing the BWB aircraft by replacing 5% of generation 2 wide body aircraft leads to a reduction of approximately 5% in the night and daytime noise contour compared to the 2050 scenario without BWB. In conclusion, integrating future aircraft concepts into the airport fleet as soon as possible holds promise for significantly decreasing the airport noise footprint. This cannot counteract the air traffic increase, but it at least minimizes the noise impact.

CRedit authorship contribution statement

Karina Einicke: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ingrid LeGriffon:** Writing – review & editing, Writing – original draft, Validation, Software, Investigation, Data curation. **John Kennedy:** Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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