Environmental Research Consultancy Department

UK Civil Aviation Authority

Aircraft Noise, Tranquillity, and Soundscape Research

CAP 3205

Published by the Civil Aviation Authority, 2026
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The latest version of this document is available online www.caa.co.uk/CAP3205

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Chapter 1
Introduction

1.1 In 2012 the CAA published a report (ERCD 1207) on the concept of tranquillity, and relevant research findings. This report aimed to provide an overview of the current area and state of knowledge of tranquillity and tranquil spaces within the UK. The paper described the importance of tranquillity for health and wellbeing, how tranquil spaces play a role in the tourist industry and economy, the methodology implemented for measurement and mapping of tranquillity, and how possible threats may impact the tranquil environment and how may be the best ways to protect tranquillity in the UK.

1.2 The current report is an update to ERCD report 1207, with a direct focus on aircraft noise and potential impacts on tranquillity. The use of soundscape research is explored in the context of aircraft noise effects, and the report includes research findings that have been published since 2012, including conference material, and academic papers, PhD theses, and book chapters. It is the aim of the report to provide an overview of the impacts of aircraft noise, tranquillity and green spaces and soundscape research to date. This report has been published to provide the public and the aviation industry with a concise and accessible update on tranquillity and soundscape research. It should be noted that the CAA has not validated any of the analysis reported at the conferences, nor takes any view on their applicability to UK policy making.

Chapter 2
Aircraft Noise and Tranquillity

2.1 Tranquillity is often defined as 'the quality or state of being tranquil; calmness; serenity, a disposition free from stress or emotion and a state of peace and quiet'. It is also described as an untroubled state, free from disturbances. The interpretation of tranquillity is often linked to engagement with the natural environment, which is the understanding of the term that will be concentrated on for the purpose of this report.

2.2 Tranquillity can be defined as 'a sense of calm or quietude' - this is the definition employed by the CAA (CAA, 2007). The Campaign to Protect Rural England (CPRE) explain that tranquil areas provide a means to escape the stress of built-up cities and towns due to the absence of intrusive man-made structures and noise that natural environments and areas offer. CPRE has defined tranquillity as 'the quality of calm experienced in places with mainly natural features and activities, free from disturbance from manmade ones' (CPRE, 2006).

2.3 ERCD report 1207 identified aviation as having the potential to impact tranquillity, with concerns arising from:

- Increasing air traffic: Projected aviation growth is expected to intensify noise exposure over rural areas, compromising historically quiet landscapes valued for recreation and wellbeing.
- Low-flying aircraft: In public perception surveys used in tranquillity mapping, both seeing and hearing low-flying aircraft appear in the top ten factors that detract from tranquillity.
- Intrusiveness in national parks and protected landscapes: Although policy does not prohibit overflight of National Parks or Areas of Outstanding Natural Beauty (AONBs), Government guidance encourages the CAA to avoid overflight below 7,000 ft where possible to help preserve tranquillity.

2.4 This chapter will focus on the area of tranquillity and includes research findings that examine the possible impacts of aircraft noise.

2.5 **Shepherd et al** researched the health-related quality of life (HRQOL) in quiet and noisy areas, with the aim to quantify how tranquillity and noise exposure (including aircraft noise) relate to health-related quality of life. The research combined data from three cross-sectional studies conducted in New Zealand, each examining different environmental soundscapes. These were pooled to compare quiet versus noisy and rural versus urban areas, producing a combined dataset of 823 adult respondents.

2.6 Four contrasting environments were selected:

- Quiet Rural (n=158): This included semi-rural greenbelt areas, with homes situated no more than 8 km from major noise sources. This area was socioeconomically matched with a noisy rural area in the study.
- Noisy Rural (n=39): Makara Valley, close to a major wind farm and residences situated within 2 km of wind turbines. This area was selected to represent industrial intrusion into a formerly tranquil rural environment.
- Noisy City (n=373): Houses within 50 m of major motorways or under the main flight path of Auckland Airport. The median transportation noise was approximately 76 dB L_{dn} (motorways) and 60-65 dB L_{dn} (airport).
- Quiet City (n=253): Houses at least 2 km from any major road or industry. This area was socioeconomically matched to noisy city areas. Median noise level of approximately 55 dB L_{dn}.

2.7 The participants were adults recruited through postal survey. Two surveys were provided per household with prepaid return envelopes, and participation was voluntary and anonymous. Factors including HRQOL, annoyance, noise sensitivity and demographics and neighbourhood issues were measured. HRQOL includes parameters on physical health, psychological wellbeing, social relationships, and environmental quality, plus two global items: overall quality of life and self-rated health. Higher scores indicate a better level of HRQOL.

2.8 Participants rated annoyance (1 = “Not annoyed at all”, 5 = “Extremely annoyed”) in respect to transport noise (aircraft, road traffic) and neighbourhood noise (e.g., neighbours, industry, turbines).

2.9 The results indicated that high annoyance to transport noise (including aircraft noise) was most prominent in the noisy city area, with around 15% of exposed residents reporting being “very annoyed”. Quiet areas indicated consistently higher HRQOL across all domains, physical, psychological, environmental, and global wellbeing, with quiet areas scoring significantly higher than noisy areas.

2.10 The results also suggested that noise annoyance is a mediator of tranquillity and health, with strong inverse dose-response relationships observed: as noise annoyance increases, HRQOL decreases across all health domains (physical, psychological, social, environmental). These relationships remained significant even after controlling for residency duration.

2.11 Of those reporting no annoyance to transportation noise, the vast majority were in the two rural areas, while fifteen percent of the noisy city sample indicated that they were very annoyed with transportation noise. The differences in transportation-induced noise annoyance between rural and city areas found in this study contribute to the general perceptions of green (quiet, spacious, and

restorative) and city (noise, crime, crowding, and stressful) areas, suggesting that “quiet” is a core characteristic of green areas.

2.12 The results suggested that annoyance predicts HRQOL better than decibel levels, indicating that annoyance is shown to be the stronger predictor of wellbeing outcomes than physical noise levels alone. This supports the integration of annoyance-based metrics and approaches into aviation noise assessments. Highly annoyed individuals had significantly lower scores in all health domains, including physical health, psychological wellbeing, social relationships, and environmental quality.

2.13 The findings suggest that tranquil and quiet areas deliver measurable health benefits, supporting their preservation in airspace design and planning. Aircraft noise and transportation noise contributes significantly to a loss of tranquillity, especially via annoyance pathways. Traditional dBA-based metrics may underestimate the impact of perceptual measures (annoyance, sense of place, masking effects) which are important for the accurate evaluation of noise.

2.14 Rural areas are particularly sensitive, implying that even modest increases in noise can disproportionately impact health and wellbeing. The findings support frameworks like the EU Environmental Noise Directive that mandate the identification and protection of quiet areas, which are demonstrably protective, offering restoration and supporting wellbeing.

2.15 **Zeng et al** used electroencephalography (EEG) to measure physiological emotional response to vegetation density and integrated sound environment within a green space. The study investigated how combinations of vegetation density (VD) and the integrated sound environment (ISE) affects human neural emotions, providing insights relevant to understanding tranquillity and the role of intrusive noise, including aircraft noise, within restorative landscapes. Although the study is not aviation-specific, it includes aircraft noise as part of the “artificial sound” category used to build sound environments, making its findings applicable to research on aircraft noise impacts on tranquillity.

2.16 The study integrated visual and sound parameters, with VD as the visual variable, with three levels: high (H), moderate, (M) and low (L). ISE was used as the sound variable, with four levels: low-decibel natural and low-decibel artificial sounds (LL), low-decibel natural and high-decibel artificial sounds (LH), high-decibel natural and low-decibel artificial sounds (HL), and high-decibel natural and high-decibel artificial sounds (HH). These two variables were combined into twelve unique groups. The ISE included natural sounds (birds, wind, water) and artificial sounds such as walking, talking, vehicles, and aircraft. Aircraft noise is explicitly used as one of the artificial sound sources that form the ISE stimuli in the experiment (grouped under “high-decibel artificial sounds” when > 65 dB).

2.17 Participants were N = 360 volunteer college students who were randomly assigned to the 12 groups (N = 30). All12 groups underwent the same five-minute high-pressure learning task (pre-test baseline), followed by a five-minute audio-visual recovery (post-test). EEG was used to measure six indicators of neural emotion (engagement, excitement, focus, interest, relaxation and stress). The pre-test score was treated as a covariate, allowing the experiment to isolate how green-space variables affected emotional recovery.

2.18 The results indicated that excitement was significantly influenced by both vegetation density and soundscape type, with significant VD and ISE interaction effects. Excitement decreased overall from pre-test to post-test, meaning recovery occurred after exposure to green-space images. However, high-decibel artificial sounds (e.g., aircraft, vehicles) modulated this reduction depending on vegetation density. High vegetation density can buffer the stressful effects of artificial noise, supporting increased excitatory but not necessarily negative arousal. This means dense vegetation can make a noisy environment more stimulating rather than overwhelming. When natural sounds were high decibel but artificial noise low, excitement peaked, which is consistent with natural sound dominance being stimulating but not stress-inducing. However, when artificial noise was high-decibel in low-vegetation settings, excitement did not increase, implying low VD offers no protection from intrusive noise such as aircraft or traffic noise.

2.19 The focus outcome was significantly affected by both VD and ISE, but without interaction. Focus was highest in low VD spaces (open views), followed by high VD, and lowest in moderate VD. High-decibel artificial + low-decibel natural (LH) produced the strongest focus response, and low-decibel natural + low-decibel artificial (LL) produced the weakest focus. This suggests that highly continuous visual scenes (either very open or fully enclosed in forest) support prolonged attention. Artificial sounds, including aircraft noise, strongly capture attention due to acoustic recognisability, salience, and inherent vigilance triggers.

2.20 It is explained that this is consistent with broader attention-restoration theory, where involuntary attention is drawn to main anthropogenic noise. Focus and relaxation metrics tended to show opposite trends, meaning artificial noise that increased focus concurrently reduced tranquillity.

2.21 For the relaxation variable, relaxation decreased from pre-test to post-test overall, but the sound environment (ISE) had a significant main effect. Relaxation was highest in low-decibel natural + low-decibel artificial (LL) settings and lowest in low-decibel natural + high-decibel artificial (LH) and high-decibel mixed environments (HH). This suggests that low noise levels, especially with natural sound dominance, promote parasympathetic recovery, which is a core component of tranquillity. High-decibel artificial noise (such as aircraft, traffic, shouting) suppresses relaxation. In summary, natural sounds accelerate

sympathetic recovery; artificial sounds slow it. This provides physiological EEG confirmation that quiet natural settings restore calm, while intrusive artificial noise diminishes tranquillity.

2.22 Vegetation density significantly affected stress; but the sound environment did not show a main effect in this study. The EEG results suggested stress was highest in low VD and high VD and was lowest in moderate VD. These results suggested that very open or very enclosed spaces create tension, possibly due to a lack of refuge (low VD) or lack of visibility (high VD). Moderate vegetation density creates the best emotional balance, enhancing tranquillity by reducing stress. Although ISE did not have a significant main effect on stress, relaxation and stress showed opposite patterns relative to sound, indicating aircraft and other artificial sounds likely disturbed stress recovery indirectly via reduced relaxation.

2.23 VD nor ISE significantly influenced the engagement or interest variable. The results indicated tranquillity is highest when vegetation density is moderate, natural sounds are dominant, and artificial sounds are low level. Aircraft noise specifically (as a high-decibel artificial sound) reduces relaxation, increases attention capture (interrupting tranquillity), prevents optimal stress recovery, and did not raise excitement in low-VD environments (i.e., there was no positive effect). Vegetation was seen to buffer, but not eliminate, artificial noise intrusion. Dense vegetation improved emotional outcomes only when artificial noise levels were not extremely high. Artificial sounds are more likely to improve focus if they are more recognisable, change in frequency more slowly, and are not jarring.

2.24 **Schäffer et al** published their findings on the association between residential greenery and noise annoyance from different sources. The aim of the study was to investigate how residential greenery (measured via normalised difference vegetation index, (NDVI) and land-use data) influences noise annoyance from road traffic, railway, and aircraft noise, using data from the NORAH study (Germany, n = 26,607). The study explored whether greenery reduces annoyance and whether this effect varies by noise source, exposure level, and environmental context. A recent study using the Swiss nation-wide SiRENE survey data suggested that residential greenery was associated with reduced road traffic and railway noise annoyance, but increased aircraft noise annoyance, a finding which was unexpected and which the authors were looking to validate with this study.

2.25 For road traffic noise, the results indicated that annoyance decreases with increasing NDVI up to approximately 60 dB L_{den}. Above 60 dB L_{den}, the trend reversed, more greenery was associated with higher annoyance. It was suggested that this was a moderating effect, and that NDVI interacts with L_{den}, and the effect is not just additive. The authors suggested that the results indicate residential greenery may buffer annoyance at low exposure levels. At high

exposure, green spaces may also be noisy, thereby reducing restorative benefits.

2.26 For railway noise, there was no consistent pattern observed across regions. Some regions show reduced annoyance with more greenery at high exposure. It was explained that this may be due to greenspaces near railways often being non-accessible or private allotments.

2.27 For aircraft noise, annoyance increased with NDVI up to approximately 55 dB L_{den}. Above 55 dB L_{den}, NDVI was found to have little effect. This confirmed the SiRENE study findings, and the authors suggested that possible reasons include that aircraft noise is intrusive and alien, especially over green spaces. There may also be visual-auditory incongruence, whereby tranquil landscapes are disrupted by aircraft. In terms of visual intrusion, aircraft were not masked by vegetation.

2.28 The authors concluded that residential greenery moderates noise annoyance, but the effects depend on the noise source, exposure level, and environmental context. They suggested that greenery is beneficial for road traffic noise, but not a substitute for traditional noise mitigation, and that urban planning should integrate greenery with acoustic considerations. They noted that the results indicated that at high road traffic noise exposure (> 60 dB L_{den}), the beneficial link of annoyance with greenery may disappear.

2.29 **Qu and Xie** investigated the effects of aircraft noise on psychophysiological parameters (Heart Rate Variability) and skin conductance.

2.30 The minute-long aircraft noise clip that was played to participants was recorded in the community in Shenzhen, China. As part of the study protocol, the researchers were also interested in the possible effects of soundscape variation such as birdsong and waterfall noises, when overlayed on the aircraft noise recordings. These generated two new modulated samples, which were adjusted to 70 dB (L_{Aeq}) to control for the effect of sound pressure levels.

2.31 Sixty participants from Shenzhen University aged between 24 and 28 were included in the study. The study design is shown in Figure 1:

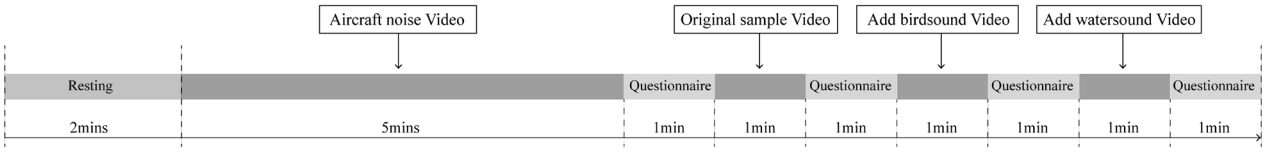

Figure 1: Study protocol

2.32 To begin with, data from the resting state for 2 min was used as the baseline index, which reflected the physiological relaxation state of the participants before noise stimulation. Then the sounds were presented in the following order: 5 minutes aircraft noise, 1 minute original aircraft sound clip, modulated samples

adding birdsong and waterfall sound, respectively. The duration of each sound interval was set to 1 minute, during which the participant filled in the corresponding questionnaire.

2.33 The results indicated that there was no association between the level of aircraft noise exposure and HRV and skin conductance. The noise samples that were superimposed with birdsong and waterfall sound significantly increased skin conductance levels (SCL), which is linked to pleasurable emotions. The soundscape masked with waterfall sound significantly increased heart rate variability (HRV), which is linked to a decrease in stress. The authors suggest that the importance of soundscape features such as waterfalls or fountains may serve to assist with modulating the negative impacts of aircraft noise.

2.34 **Schäffer et al** examined whether residential green (measured in several ways, especially normalised difference vegetation index, NDVI) modifies transportation noise annoyance (road, railway, aircraft noise) across Switzerland, and whether these relationships vary by the degree of urbanisation. As tranquillity is closely tied to green settings, natural sounds, and low intrusive noise, understanding how aircraft noise interacts with greenery is critical for designing and protecting restorative places.

2.35 Noise and annoyance data was taken from the Swiss SiRENE survey (2014-2015), with calculated source-specific L_{den} at each dwelling and ICBEN 0-10 annoyance ratings recoded to “highly annoyed” (HA ≥ 8) for road, rail, and aircraft nose. In total, 5,592 respondents geographically spread across the country participated in the survey. Individuals with no calculated exposure or exposure below 30 dB L_{den} for the primary noise source were excluded from the analysis. Each respondent provided one, two, or three annoyance ratings depending on the number of transportation noise sources above 30 dB L_{den} they were simultaneously exposed to. This resulted in a total of 12,064 observations, 5431 (road traffic), 3536 (railway) and 3097 (aircraft).

2.36 A range of “green metrics” were analysed, representing residential greenness, visible vegetation from home, green and/or natural spaces as well as their accessibility and noise pollution, and landscape suitability for nearby recreation. The authors used logistic regression analysis to establish exposure-response curves (ERCs) to quantify the associations of the transportation noise source, residential green and degree of urbanisation with noise annoyance.

2.37 The results indicated that across Switzerland, a higher degree of residential green was associated with higher aircraft noise annoyance. Translating the shift into “dB-equivalents,” moving from low to high greenness corresponded to an increase of 8.8 to 10.7 dB L_{den} needed to reach the same level of annoyance i.e., green made aircraft noise feel more intrusive. In contrast, residential green lowered annoyance to road traffic (approximately minus 6 dB L_{den}), and to a lesser extent railway noise annoyance (approximately minus 3 dB L_{den}).

2.38 When the authors examined quiet green (green areas with low total transport noise) and visible vegetation from home, the largest increases in aircraft noise annoyance were found, suggesting the more tranquil the green setting, the more pronounced and disturbing aircraft overflights became.

2.39 The authors suggested theories for the difference between the annoyance findings for road and railway noise compared to aircraft noise.

- Firstly, there may be incongruence with natural settings. Aircraft overflights violate expectations for natural quiet in green places, which may result in heightened annoyance.
- Lack of “escape”: Unlike road/rail noise, aircraft sound cannot be avoided by walking deeper into a park; it overflies the very spaces meant for restoration.
- Alien, intermittent salience: Aircraft noise is intermittent, high-energy and “alien” to the setting; such events may capture attention and disrupt calm more than continuous, context-congruent sources such as road noise.

2.40 The authors suggest that further studies to confirm this finding and to better understand the underlying mechanisms are required. The provision of residential green should be fostered in city planning, particularly in rapidly growing urban areas, to preserve or create visual and acoustic qualities in densely populated areas. Tranquillity depends on audio-visual coherence; where overflight is unavoidable, planners should prioritise buffering of events while enhancing positive natural sounds (water, birds) that support restoration, recognising that these do not cancel aircraft noise, but may help mitigate flyover events.

2.41 **Kawai et al** studied the association between noise exposure, stress, and characteristics of green spaces. The report presents the research protocol and pilot findings for the RESTORE (Restorative potential of green spaces in noise-polluted environments) project, which investigates how green spaces and environmental noise, especially road traffic noise, jointly influence noise annoyance, perceived stress, and physiological stress among residents in Zurich, Switzerland.

2.42 The rationale for the study was that over 125 million Europeans are exposed to noise levels above 55 dB L_{den}, with consequences including noise annoyance, sleep disturbance, physiological stress reactions, and increased cardiovascular risk and mortality. Green spaces may mitigate these effects by offering restorative environments. Previous studies show that access to quiet natural areas can reduce noise annoyance and support stress recovery. However, the combined pathways linking noise exposure, annoyance, perceived stress, and physiological stress are not yet fully understood. The RESTORE project aimed to address this gap.

2.43 The study included two large cross-sectional surveys from Zurich (ZH) N = 1,111 participants, and a nationwide Swiss study (CH) N = 2,229 participants. The main objective was to quantify the relationship between road traffic noise exposure, annoyance, and greenness (measured using normalised difference vegetation index NDVI), and to understand how different noise sources, including aircraft noise, contribute to overall noise annoyance.

2.44 Data was collected in spring/summer 2022 (both samples), with an additional ZH wave in summer 2023. Addresses were provided by municipal/federal authorities, and invitation letters with a web/QR link were sent to 7,368 (ZH) and 20,000 (CH) invitees.

2.45 Residential green was found to have a strong mitigating effect in the nationwide sample (CH). Higher residential greenness significantly reduced road traffic noise annoyance, and increasing NDVI from the 5th to 95th percentile reduced perceived noise by the equivalent of 4 dB. The effect was weaker in the Zurich sample, with greenness indicating a non-significant 3 dB mitigating effect, likely because Zurich has less variance in green space and fewer highly green residential areas.

2.46 Aircraft noise was not a primary focus of the study (because areas with high aircraft noise exposure were intentionally excluded during stratification). However, aircraft noise was still assessed as part of the questionnaire and the study explicitly discusses why aircraft noise matters for annoyance research.

2.47 Residential areas with aircraft noise above 45 dB (ZH) and 57 dB (CH) were excluded to isolate the effects of road traffic noise, but survey respondents rated their annoyance from aircraft noise in the questionnaire (ICBEN scale). A prior Swiss study by Schäffer et al found residential green reduces annoyance to road and rail noise but increases annoyance to aircraft noise. This pattern, where green makes aircraft noise more noticeable is consistent with tranquillity research suggesting that natural quiet amplifies the contrast of intermittent, high-salience aircraft noise and that people in greener/quiet spaces expect tranquillity, making aircraft noise seem more disruptive.

2.48 The authors emphasised that noise reduction policies and urban greening strategies should be integrated, acknowledging both the restorative potential of nature and the unique disruptive qualities of aircraft noise.

2.49 **Lugten** published their PhD thesis on tranquillity by design: architectural and landscape interventions to improve the soundscape quality in urban areas exposed to aircraft noise. The rationale for the work was although aircraft are becoming acoustically quieter, public annoyance and complaints around airports are not falling. In several major airport regions (Amsterdam, Heathrow, Frankfurt), complaints have even increased despite measurable decreases in average sound exposure. The study's rationale emerges from the need to

understand this mismatch and to identify new strategies for managing the impact of aircraft noise on human well-being. Urban design has strong and well-studied effects on road-traffic noise, but there is almost no equivalent knowledge for aircraft noise.

2.50 The aims of the study were to:

- Reveal whether architecture and urban design can meaningfully reduce aircraft noise exposure outdoors, not just inside insulated buildings.
- Develop a modelling method that could accurately simulate aircraft noise within complex-built environments, enabling design-oriented experimentation.
- Assess whether natural elements like moving water and vegetation can enhance soundscape quality, improving perceived tranquillity even when noise levels remain high.
- Provide evidence-based design guidance so that planners, architects, and airport authorities have practical tools, alongside contour maps, to improve quality of life in airport regions.
- Bridge the gap between engineering acoustics and human-centred soundscape research, offering an integrated approach to noise, perception, and place.

2.51 The main findings from this work are were:

1. When aircraft-noise exposure is compared against experienced tranquillity, existing metrics are not enough to adequately reflect the lived experience of people. Average exposure metrics (e.g., L_{den} / L_{Aeq}) explain only a modest share of how people actually react to overflights. Event characteristics (peak L_{Amax}, number/timing of flyovers) and context (activity, indoors/outdoors, perceived control/fairness) better predict the loss of tranquillity. In terms of practical implications, when assessing/restoring tranquillity, it is suggested to supplement L_{den} with event-based metrics and place/time context.
2. Quiet façades exist for aircraft noise, and design can create them. In situ multi-site measurements near Amsterdam Schiphol revealed that shielded ("quiet") facades achieved approximately 2-13 dBA L_{Aeq} mean reduction when compared to exposed sides; L_{Amax} at shielded sides was typically less than 65 dBA, indicating meaningful local relief during events. Taller buildings increased shielding and bayed/protruding forms shortened exposure duration. These benefits were frequency dependent (better above around 200 Hz) and geometry dependent (non-linear relation to aircraft "slant angle"). The practical implication is proposed as an aim for ≥10 dB exposed-shielded differential to create outdoor/indoor refuges, and target height and façade articulation to increase calm zones.

3. Nature based soundscape interventions improve perceived tranquillity, even when the sound level change is small. In a virtual reality soundscape experiment (41 participants; sixteen urban scenarios; aircraft 60-70 dBA) the results indicated that adding vegetation and moving water significantly increased soundscape "pleasantness" and "eventfulness." Typical gains were +6-10% for either vegetation or water alone; +13-16% (pleasantness) and +20-26% (eventfulness) when combined, with largest effects at 70dBA and in residential areas. Moving water often became the dominant perceived source, suggesting evidence of informational masking/attentional re-weighting (i.e., improved perception without strict masking of aircraft noise). The practical implication is proposed as pairing greenery with well-designed water features to shift attention and restore congruence between what people see and hear. Tranquillity depends on the coherence between what is seen and heard and on the availability of gently varying natural cues. Strategically designed water features and visible greenery increase the appropriateness and restorative feel of a place and can deliver perceptual gains, even if dB values change little.

4. A modelling method to plan tranquillity. The thesis develops and validates an intermediate propagation method that brings buildings and refraction into aircraft noise prediction at urban scales, something standard airport noise tools lack. The practical implication is that planners can simulate design scenarios to see where quiet sides and calm pockets emerge before commencing building.

2.52 The author concludes that the thesis demonstrates that tranquillity under flight paths is designable, by combining refraction-aware urban form (to physically lower peaks where people live) with nature-based soundscape strategies (to redirect attention and improve audiovisual congruence), planners can deliver tangible calm that conventional L_{den} maps cannot foresee.

2.53 **Dalley** published work on tranquillity mapping for soundscape management. The aim was to develop a method to map tranquillity (as a proxy for soundscape quality) in two New Zealand national parks, Aoraki/Mount Cook and Westland Tai Poutini, so park managers could visualise where and when visitors experience tranquil conditions. Another aim was to adapt and calibrate the Tranquillity Rating Prediction Tool (TRAPT) for a New Zealand setting dominated by helicopter noise, then combine it with aviation noise modelling (Aviation Environment Design Tool - AEDT) and GIS to create tranquillity-duration contour maps (measured by hours per day at “excellent” tranquillity).

2.54 Tranquillity is a perceptual measure influenced by both visual naturalness and anthropogenic noise; TRAPT merges these into a single rating (0–10). In national parks, the percentage of natural features (NCF) is around 100%, so noise level is the dominant driver of perceived tranquillity. The project aimed to

study beyond simple noise thresholds, aiming to represent how tranquil a place feels to visitors, not only how loud it is.

2.55 The author measured and recorded helicopter flyovers plus natural ambiences across multiple sites and captured landscape video. Thirty-five participants viewed the park video while listening to ten second audio clips spanning low to high L_{Aeq} levels, primarily helicopter sounds. They rated perceived tranquillity for each clip, enabling a NZ-specific calibration of TRAPT.

2.56 GPS-logged helicopter flight corridors were used to calculate a Time Above (TA) metric at a 100x100 metre grid for a typical ten-hour operating day. TA was then converted to hours per day of "excellent tranquillity" (TR ≥ 8) using the calibrated TRAPT threshold, and static and interactive web maps were produced.

2.57 Helicopters were the principal anthropogenic noise source impacting tranquillity in these NZ parks. Where flights clustered together, tranquil time was markedly reduced.

2.58 To achieve "excellent tranquillity" amidst aircraft activity, the author suggested ambient L_{Aeq} must stay ≤ 32 dBA, which they acknowledge is a demanding threshold that underscores how sensitive natural soundscapes are to overflights. The mapping approach provides actionable, place-based evidence to manage aircraft noise impacts even where overflight control is institutionally constrained. This pilot study focused on helicopters only (as the dominant source), but future phases of the studies are proposed to add fixed-wing aircraft and other transport sources. It is explained that static figures and an interactive map may help communicate where aircraft operations most impact tranquillity, which may be useful for public engagement and policy discussions.

2.59 **Dedieu et al** investigated virtual reality simulated aircraft flyovers and how the landscape can influence the pleasantness of the environment. Pleasantness is a construct strongly linked to tranquillity. Using a virtual reality (VR) aircraft noise simulator developed within the EU ANIMA project, the experiment examined whether different landscapes (urban versus park) changed how people experience aircraft flyovers.

2.60 Sixty participants experienced twelve aircraft flyover scenarios in two different 360° VR environments: an urban square and a green park. Each stimulus included auralised aircraft noise, simulated for three aircraft types:

- A380 (loudest) 70.9 dB L_{eq}, maximum SPL (30s) 76.1 dB
- A320 neo 65.4 dB L_{eq}, maximum SPL (30s) 72.1 dB
- BOLT (a low-noise future concept aircraft) 65 dB L_{eq}, maximum SPL (30s) 71.3 dB

2.61 Aircraft flyovers were reproduced binaurally, with head-tracking used for directional realism. All aircraft sounds were mixed with light natural background noise (birds, wind). The set-up replicated the auditory-visual experience of aircraft noise exposure while controlling for environmental variables.

2.62 The results suggested that landscape did not significantly change overall perceived pleasantness of aircraft flyovers. Statistical analysis found no significant difference in participants' pleasantness ratings between hearing the same aircraft noise in a park versus an urban district. This suggests that aircraft noise dominates the perceived quality of the environment, regardless of whether the surroundings are predominantly green, or built-up.

2.63 Although statistically there was no global difference between groups, there were two opposing reactions to the aircraft flyovers within the groups. The first group were those who prefer aircraft noise in the urban district. These participants felt aircraft noise was more disruptive in a park, where they expected tranquillity. This group reflects a loss of tranquillity caused by aircraft noise intruding into an otherwise natural, quiet environment. Aircraft noise violated their mental model of what a park should sound like. The second group preferred aircraft noise in the park. These participants found aircraft noise more bearable in a green setting, because the park felt inherently pleasant. They found the urban setting oppressive, so aircraft noise felt more compounded. This suggests that visual pleasantness can partially offset aircraft noise impacts for some people. A third group, most people, rated flyovers similarly in both landscapes, meaning aircraft noise was the overriding perceptual factor.

2.64 Some of the conclusions from this study included the suggestion that tranquillity, or pleasantness, is context-dependent:

- Aircraft noise disrupts tranquillity more when people expect quiet (e.g., parks).
- Aircraft noise can outweigh visual benefits: Even attractive settings cannot fully compensate for noise intrusion for many people.
- The importance of expectation and congruence: Noise is seen as more annoying when it is incongruent with the visual environment.
- VR is a powerful tool for understanding how aircraft noise affects perceived tranquillity under realistic conditions.

Chapter 3

Soundscape research and aircraft noise

What are soundscapes?

3.1 A soundscape refers to the acoustic environment as it is perceived, experienced, and understood by people, in context. It is not just about sound levels or physical noise measurements, but about human perception, meaning, and place. In soundscape research sound is not automatically “noise,” and the same sound can be perceived as pleasant, neutral, or disturbing depending on:

- Context
- Expectations
- Activity
- Cultural and social factors
- Visual surroundings

3.2 Soundscape research represents a fundamental shift from noise control (reducing unwanted sound) to experience-oriented design and management of acoustic environments. The official ISO definition is “Soundscape: an acoustic environment as perceived or experienced and/or understood by a person or people, in context.” (ISO 12913-1:2014). This definition has three essential components:

1. Acoustic environment: The collection of all sounds present in a location. This includes natural, human, and technological sources.

2. Perception/experience: Emphasises that soundscape exists in the listener, not just in the environment. Recognises emotional, cognitive, and behavioural responses.

3. Context: Includes visual surroundings, activity and purpose of the place, social and cultural meaning, and time of day. Context determines whether a sound is appropriate or intrusive. Without a listener and a context, a soundscape does not exist under the ISO definition.

Why the soundscape concept was developed

3.3 Limitations of traditional noise assessment and traditional environmental acoustics assumes sound equals noise if it exceeds a certain threshold, and the lower the sound level, the more desirable the environment. However, decades of research showed that noise annoyance may correlate poorly with average sound levels. The same sound level can provoke very different reactions, for example,

some loud places are enjoyable (markets, festivals), and some quiet places may feel uncomfortable or unsafe. Soundscape research emerged to explain why people react differently to sound. This area integrates psychology, acoustics, landscape, and planning.

Purpose of soundscapes

3.4 To improve environmental quality, the use of soundscapes aims to enhance well-being, comfort, and restoration, support places for relaxation, social interaction, or focus, and to go beyond mitigation towards positive acoustic design.

3.5 The aim is also to reframe how “noise” is addressed. Instead of asking ‘how do we eliminate sound?’ soundscape research asks ‘which sounds should be reduced, which enhanced, and which are appropriate here?’

3.6 Soundscape research aims to support planning and policy decisions. Soundscape approaches are now used in:

- Urban design and placemaking
- Transport and infrastructure planning
- Landscape architecture
- Environmental impact assessment
- National parks and quiet-area protection

3.7 They are particularly valuable where standard noise limits fail to reflect lived experience, multiple sound sources interact, or the expectations of calm or liveliness differ by place.

3.8 They also aim to address context-sensitive noise issues (e.g. aircraft noise) in contexts such as parks or green spaces, residential areas, and tranquil spaces. Soundscape research suggests that aircraft noise may be far more disturbing where people expect quiet, visual context can amplify or moderate annoyance, and perceived control plays a critical role in the response to noise. This has made soundscapes central to tranquillity research, and community response to aircraft noise.

Soundscapes and aircraft noise research

3.9 Traditional aircraft noise research has historically focused on physical exposure (e.g. L_{den}, L_{Aeq}, L_{Amax}), with the aim of producing exposure-response relationships (noise level versus % highly annoyed), for compliance with thresholds and contours.

3.10 This approach treats aircraft noise as a pollutant, assumed to affect people uniformly once sound levels exceed limits. Soundscape research reframes

aircraft noise as one sound source within a wider acoustic environment, whose impact depends on perception and context.

3.11 Under ISO 12913, aircraft noise is not interpreted in isolation, but as part of an acoustic environment perceived in a specific place, at a specific time, by specific people. Aircraft noise is studied in relation to where and how it is heard within the context (e.g. park, home, city, garden), which becomes as important as decibel levels. Human interpretation and expectation become central variables to the research. Soundscape research explicitly addresses expectation, congruence between sound and place, the meaning of sound sources, and loss of tranquillity, not just loudness.

3.12 Variables such as pleasantness, eventfulness, and appropriateness are often used, in addition to visual intrusion and the temporal landscape (timing of aircraft noise). Soundscape approaches allow researchers to:

- Explain why annoyance does not decline with quieter aircraft.
- Study loss of tranquillity.
- Distinguish acoustic harm from experiential harm.
- Integrate landscape design, urban form, and nature-based interventions.
- Design supplementary metrics to decibels alone.

3.13 Applied to aircraft noise, soundscape concepts shift research from measuring sound exposure to understanding how aircraft sounds are perceived, interpreted, and valued within specific places and moments. They explain why aircraft noise can be highly disturbing even at low levels, particularly in tranquil or natural settings, due to expectation, lack of control, and audio-visual incongruence. By incorporating perception, context, and meaning, soundscape research provides a framework for addressing aviation noise impacts that traditional exposure-based approaches cannot fully explain or resolve.

3.14 The consideration of non-acoustic factors is important in transportation noise research, including soundscapes. ISO/TS 16755-1:2025, published in May 2025 is the primary international standard addressing non-acoustic factors influencing the perception, interpretation, and response to environmental sounds. It provides a framework for measuring and reporting personal, psychosocial, and situational factors, complementing noise assessment standards and includes the following aspects:

- Definition: Defines "non-acoustic factors" (or context factors) as variables—other than the sound itself—that influence how people perceive and react to sound.

- Categories: The standard covers personal, psychosocial, environmental, and situational factors.
- Purpose: It is used for assessing health outcomes, designing, and managing soundscape interventions.
- Application: It aids in improving the interpretation of socio-acoustic surveys, which often rely on specific, non-standardised questions.

3.15 This chapter outlines some of the most relevant research findings in soundscapes with relation to aircraft noise. It is beyond the scope of the report to include every publication since 2012 in detail, but it is the intention that this chapter will provide an overview of the research area.

Soundscapes, aircraft noise, and health

3.16 **Gerolymatou et al** assessed health effects and soundscape analysis as new mitigation actions for aircraft noise impacts in small and middle-sized urban areas in Greece. The first aim of the study was to use strategic noise mapping to assess the impact of aircraft noise on residents and tourists, exploring how much aircraft noise people are exposed to, how this noise affects health, annoyance, sleep, and quality of life, and how aircraft noise is perceived.

3.17 The second aim was to quantify health effects using WHO's DALY model. The study aimed to calculate the burden of disease caused specifically by aircraft noise, expressed as Disability-Adjusted Life Years (DALYs), including cardiovascular impacts, sleep disturbance, annoyance, cognitive impairment in children and tinnitus.

3.18 The third aim was to use soundscape analysis to develop better noise mitigation strategies. Beyond noise levels, the project aimed to understand:

- How people experience the entire sound environment.
- How aircraft noise interacts with local culture, urban form, and daily routines.
- How to design mitigation plans that also improve the positive, non-aircraft parts of the local soundscape.

3.19 The objective was to produce holistic, realistic noise action plans that combine engineering noise mapping, health impact science, human perception, and urban context. Two airports were included in the study: Heraklion, (Crete), and Corfu.

3.20 For Heraklion Airport, a significant portion of the population is exposed to aircraft noise, with 3.8% exposed to >70 dB L_{den}, and 6.3% exposed to >60 dB $L_{night.}$ At this location, aircraft noise is perceived as a major annoyance source, despite moderate average L_{den}/L_{night} levels. The calculated total aircraft noise induced DALYs were 1,336 per year (around 0.92% of the city population). This was a

higher health burden due to a larger population density and continuous year-round airport activity.

3.21 For Corfu airport, aircraft noise exposure is lower, with 0% exposed to >70 dB L_{den}, and 0.1% exposed to >60 dB L_{night}. Despite fewer heavily exposed residents, aircraft movements are the dominant sound source and frequently noted by both residents and tourists. Total aircraft-noise DALYs were 170 per year (around 0.55% of the city population). Seasonal airport activity and lower population density reduced the overall health impact.

3.22 In terms of community perception and soundscape findings, for Heraklion, around 80% of residents found aircraft noise annoying, with 17-20% reporting being “resigned” or “used to it”. The soundscape is dominated by aircraft noise, which frequently masks other environmental sounds. When aircraft are not present, the area possesses other local sound identities (e.g., beach area, small urban square).

3.23 For Corfu, aircraft noise was sometimes disruptive (especially to workers), but often an attraction for tourists, who come specifically to watch/hear take-offs and landings. Residents generally described the environment as quiet outside aircraft events. Aircraft noise was acknowledged but not widely considered a severe daily nuisance.

3.24 The overall conclusions were that Heraklion Airport causes significant aircraft noise impacts, with notable burdens on health, speech masking, and community annoyance. Mitigation measures considered include relocation of the airport in order to maintain the quietness of the area when no aircraft are present. Corfu Airport produces a lower health and exposure burden, and aircraft noise forms part of the tourist experience. It was therefore suggested that noise can be managed through planning and preserving quiet zones.

3.25 **Aletta et al** examined the associations between positive health-related effects and soundscapes. This was a systematic review that investigated whether positive soundscapes, defined as acoustic environments perceived as pleasant, calm, vibrant, or minimally annoying, are associated with positive health-related outcomes. Building on ISO’s definition of soundscape as an acoustic environment “as perceived by people, in context,” the review aimed to understand whether the subjective experience of sound can promote health, rather than merely avoiding harm.

3.26 The researchers screened 130 scientific papers, including seven studies (2783 total participants) that simultaneously measured soundscape perceptions and health indicators. These studies fell into two categories: large-scale socio-acoustic surveys using self-reported psychological health measures, and controlled laboratory studies using physiological stress markers.

3.27 Across both categories, the findings consistently indicated that positively perceived soundscapes are linked to better health outcomes, while negatively perceived soundscapes, particularly those generating annoyance, are associated with poorer health and well-being.

3.28 Three large studies explored links between everyday soundscape experience and people's self-reported health, well-being, and quality of life. They consistently found that lower noise annoyance was correlated with better physical and psychological health. Participants reporting less annoyance also reported fewer symptoms such as tiredness, stress, headaches, irritability, and social withdrawal. Another study showed that individuals with better general health expressed a lower "need for quietness," indicating greater contentment with their everyday soundscape. A further investigation across rural, suburban, and airport-adjacent communities found that people who were "most annoyed" by their sound environment scored significantly lower in all major Health-Related Quality of Life (HRQOL) domains: physical, psychological, social, and environmental. Collectively, these studies suggest that annoyance is a strong predictor of poorer self-reported health, and conversely, positive soundscape appraisal aligns with improved well-being.

3.29 Four controlled laboratory studies examined the influence of soundscapes on autonomic nervous system activity, using measures such as skin conductance level (SCL), heart rate (HR), heart rate variability, respiration rate, and electromyography. Across these experiments, pleasant soundscapes including natural sounds consistently facilitated faster physiological recovery from stress. Participants exposed to pleasant, familiar, or calm environments showed more rapid decreases in SCL, indicating reduced sympathetic arousal and improved restoration. Meanwhile, unpleasant, or dominant sounds (e.g., traffic noise, construction noise, aircraft noise) produced slower recovery, sustained arousal, or increased stress indicators. Several studies confirmed that pleasant soundscapes lead to health-supportive autonomic patterns, such as steadier HR and increased respiration linked with relaxation. Together, these findings demonstrate that soundscape appeal directly influences the body's capacity to recover from stress, highlighting a measurable physiological benefit of positive acoustic environments.

3.30 The review proposed that public health and environmental planning should move beyond noise reduction alone and instead actively develop positive, health-supportive soundscapes. This includes valuing beneficial sounds (e.g., nature, social activity) and designing environments that enhance perceptual well-being, not simply reduce harmful exposure.

3.31 **Lercher** et al, in their authored chapter within *Soundscapes and the Built Environment*, examine how transportation noise, especially aircraft noise, and perceived soundscapes interact with health-related quality of life, mental

well-being, restoration, and contextual factors. It integrates findings from several Dutch studies, including those around Schiphol Airport, and medium-scale studies involving transport corridors.

3.32 Aircraft noise was one of the key transportation sources evaluated using L_{den} and L_{night} indices. In the Schiphol Monitor studies (2002, 2005), aircraft noise exposure was estimated for residents near Schiphol Airport and linked with annoyance, sleep disturbance, general health, and mental health.

3.33 Residents rated aircraft noise using 0-10 ISO annoyance scales, and noise exposure at their address was modelled using Dutch GIS-based methods. Higher aircraft noise levels corresponded with significantly higher percentages of severe annoyance and sleep disturbance.

3.34 A main finding was that people's perception of their acoustic environment, or soundscape, is as important, or more important than the physical noise level itself. Two main soundscape dimensions were identified:

- Negative soundscape (loud, aggravating, sharp, intrusive, stressful).
- Positive soundscape (calming, pleasant, exciting, light).

3.35 Aircraft noise strongly predicted the negative soundscape score. A significant linear association between aircraft L_{den} noise categories and percentage of residents reporting a highly negative soundscape was observed. When aircraft noise was above around 55 dB L_{den}, positive soundscape perception decreased steeply.

3.36 For health outcomes, negative soundscapes were linked to poorer mental health. Residents with a negative soundscape perception had higher psychological distress (GHQ), higher prevalence and incidence of depression or anxiety, more severe annoyance from aircraft, road, and rail noise and lower vitality score.

3.37 Positive soundscapes were linked to better well-being. Those rating their sound environment positively showed higher vitality, less need for quiet, more visits to quiet areas, and lower dissatisfaction with access to quiet spaces.

3.38 A recurring theme was the restorative role of quiet areas in mitigating aircraft noise impacts. People with more negative aircraft-dominated soundscapes have a stronger need for quiet and are less satisfied with access to quiet places. "Restoration" variables such as being away, fascination, and compatibility were found to buffer negative health outcomes even at higher levels of aircraft noise. In structural equation modelling (SEM), perceived restorative-ness of the home environment showed direct positive effects on health, even when aircraft noise exposure was high.

3.39 Aircraft noise contributes not only to personal annoyance but also to neighbourhood dissatisfaction. Higher aircraft noise levels correlated with poorer

ratings of safety, recreation opportunities, and general living quality. The emotional response to aircraft noise and coping behaviours predicted neighbourhood dissatisfaction more strongly than noise level alone. The authors concluded that negative soundscape dimension is comparable to “aircraft noise annoyance,” confirming that annoyance is a perceptual construct embedded in broader soundscape experience.

Perception of environment

3.40 **Vassallo et al** investigated how visual exposure to urban greenery, specifically courtyard trees, affects the perception of aircraft noise during flyover events, using an audio-visual Virtual Reality (VR) experiment. Soundscape research emphasises perceptual experience of noise, rather than solely noise levels. Prior research suggests that greenery can reduce road and railway noise annoyance, but evidence regarding aircraft noise remains limited and inconsistent. This study aimed to address that gap by isolating non-acoustic factors (visual greenery) using controlled VR environments.

3.41 There were two VR conditions, so participants (N=33) experienced two versions of the same residential courtyard in a randomised order:

- Trees condition: courtyard contains eight mature European Hornbeam trees.
- No Trees condition: identical courtyard but without any trees.

3.42 Two real-world recordings were combined and kept identical between conditions:

- Urban background sound (2 min 30 seconds in total)
- Aircraft flyover starting at 1 minute into the presentation, lasting for one minute.

3.43 Only the visual scene differed between the two conditions, the audio (aircraft noise plus background sound) remained the same in both. This design isolated the non-acoustic effect of greenery on aircraft noise perception. Participants completed soundscape questionnaires based on ISO/TS 12913-2:2018 soundscape assessment tools, adapted for VR.

3.44 Participants rated how strongly they agreed (1 = strongly agree, 7 = strongly disagree) that the environment was:

- Pleasant
- Chaotic
- Vibrant
- Uneventful
- Calm

- Annoying
- Eventful
- Monotonous
- Loud

3.45 The main outcome analysed was ‘pleasantness,’ with resulting categorisation into Pleasant, Neutral, and Unpleasant groups. The results indicated that participants rated the aircraft noise environment as significantly more pleasant when trees were present, and less unpleasant compared to the no-trees condition. The mean pleasantness rating improved from 4.97 to 4.24 when trees were added. The proportion of “Unpleasant” ratings dropped from 63% to 36%, and the proportion of “Pleasant” ratings more than doubled from 18.2% to 39.4%.

3.46 The authors concluded that greenery increased feelings of pleasantness and reduced annoyance, suggesting that visual context can shift participants from negative to neutral or positive soundscape evaluations. This aligns with broader soundscape research showing that visual nature cues can "mask" or moderate negative emotional responses to noise. Perception of noise is not a direct function of sound pressure levels alone.

3.47 The authors highlighted ideas for future soundscape research on aircraft noise, including testing different greenery densities or species, including biophonic and geophonic sounds (birds, rustling leaves), exploring seasonality, canopy volume, and growth stages, and conducting in-situ experiments in real courtyards near flight paths.

3.48 **Cal et al** conducted a scoping review to explore how the soundscape approach has been applied to schools, examining how students and teachers perceive their acoustic environments. The review covered eleven studies (2000–2023) and identified patterns in age groups studied, sound sources examined, and methodological approaches used.

3.49 Primary school children were found to be the most commonly studied group, with research focused heavily on negative sounds, especially noise from road traffic and other urban environmental sources. Most studies used questionnaires, often complemented by interviews, or mixed methods, and positive or restorative sounds (e.g., nature, music) were rarely assessed, representing a major research gap.

3.50 Aircraft noise was included in three of the reviewed studies, and the review noted that nearly half of the studies focusing on negative sound sources address outdoor noises, particularly road traffic and aircraft noise. The fist of these three studies (López Barrio, 2003) examined children’s affective and cognitive responses to aircraft noise. The study specifically evaluated negative effects of

aircraft and road traffic noise on children's soundscape perception both at school and at home. The study used questionnaires and qualitative tasks (drawings, essays) with 283 students. It assessed emotional interpretations and pleasantness of environments. Aircraft noise was identified as a contributor to negative emotional and perceptual responses within the school soundscape.

3.51 The second study was the RANCH study (Matheson et al, 2003), which examined road and aircraft noise exposure in relation to episodic memory, cued recall, recognition, and prospective memory. For the 2,844 children included, the researchers reported that there was no significant relationship found between aircraft noise exposure and children's ability to recall or recognise information. The authors concluded that aircraft and road noise did not show a consistent influence on memory performance.

3.52 The third study including aircraft noise was by Nilsson et al, 2003 which compared children attending schools near aircraft flight paths with those who were not exposed. No meaningful differences were observed in children's emotional evaluations of soundscapes. Past experience with aircraft noise was not found to influence perceived pleasantness of the environment.

3.53 The review suggests that although aircraft noise is not the primary focus of school soundscape studies, it is consistently present in research examining negative outdoor sound sources. The included studies indicated that its effects are perceptually negative in some contexts (annoyance, emotional response), not consistently linked to memory or cognitive deficits, and not necessarily influential in shaping children's broader soundscape judgments.

3.54 It is concluded that aircraft noise is an important yet underexplored dimension of school soundscape research, and future studies may benefit from investigating it within more holistic, multisensory, and context-based frameworks.

3.55 **Liu et al** published a study investigating how the general public defines and perceives noise, using analysis of interviews with seventy-eight participants. It develops a conceptual model situating noise within the interactions among sound, environment, and humans, offering an expanded human-centred understanding of noise that aligns closely with contemporary soundscape research.

3.56 Although the report does not focus exclusively on any single noise source, aircraft noise emerges within the broader discussion of environmental noise, noise challenges, and the evolution of soundscape thinking. The authors highlight that traditional noise metrics (e.g., L_{den} used for airports) do not capture subjective experience. They reference the emerging Soundscape Indices (SSID) approach, which incorporates psychological, psychoacoustic, physiological, and contextual factors. This suggests that future aircraft-noise assessment should integrate perceived sound quality, annoyance influenced by context, vulnerability

factors, and multi-sensory interactions. This marks a conceptual shift from "aircraft noise reduction" to aircraft soundscape design, aligning with modern policies in environmental acoustics.

3.57 The study indicates that noise perception, including aircraft noise is shaped by:

- Time: People detect aircraft noise more strongly at night or during rest.
- Space and context: A sound (including aircraft) becomes noise depending on location (e.g., quiet versus busy areas).
- Psychological state: Negative mood increases annoyance, even from typical environmental noise. This mirrors findings in aircraft-noise research linking stress, sensitivity, and health outcomes.
- Sensitivity and vulnerability: Children, older adults, patients, and individuals with poor sleep or high sensitivity respond more strongly to environmental noise (including aircraft noise).

3.58 The report highlights that effective noise management, particularly for large-scale sources like aircraft, must incorporate public perceptions, consider vulnerable groups, move beyond decibel-based limits, and include soundscape thinking, not only noise reduction. A shift is proposed from "noise control" to designing positive, context-aware, human-centred acoustic environments, even for unavoidable sources such as aircraft.

Noise annoyance

3.59 **Mitchell et al** investigated how soundscape complexity, defined as the number and type of identifiable sound sources in an acoustic environment, affects urban noise annoyance. The study used a large-scale online listening experiment involving 1,221 participants and 2,890 binaural recordings of real-world urban environments from the International Soundscape Database. The primary aim was to understand how combinations, counts, and specific types of sound sources contribute to perceived annoyance, moving beyond traditional transportation noise-only approaches.

3.60 Participants listened to fifteen-second audio recordings, identified audible sound sources (from a list of twenty-four, including aircraft noise), and rated their annoyance on a ten-point scale. The study addressed three research questions:

- Do specific combinations of sound sources influence annoyance?
- Does the number of identifiable sound sources (soundscape complexity) influence annoyance?
- Do specific sound sources independently increase or decrease annoyance?

3.61 The findings suggested that sound source combinations do not significantly affect annoyance. Analyses showed that different combinations of sound sources did not produce meaningful differences in annoyance ratings. This contradicts the expectation that certain pleasant/annoying combinations (e.g., traffic noise and bird sound) might interact.

3.62 The findings also revealed that soundscape complexity has a strong non-linear relationship with annoyance. The number of identifiable sound sources had a clear and statistically significant effect. The lowest annoyance occurred when two clearly distinguishable sound sources were present. Annoyance increased when no sources could be identified (monotonous/uneventful soundscape) or many overlapping sources were present (chaotic/overloaded soundscape). The authors explain that this finding aligns with soundscape information load theory and Schafer's hi-fi/lo-fi framework: i.e. moderate complexity is perceived as more pleasant than either overly sparse or overly dense acoustic environments.

3.63 Specific sound sources were found to influence annoyance. Transport-related sounds had the strongest effect, with aircraft noise producing the strongest response. When aircraft noise was present, mean annoyance ratings were significantly higher (3.71 versus 3.33 when absent; $p = 0.013$). Nature-related sounds and soft human environment sounds such as birdsong, rustling leaves, footsteps, reduced annoyance.

3.64 The authors concluded that annoyance is shaped not only by noise level or source type but by soundscape complexity and presence of beneficial natural sounds. Moderate soundscape complexity (two identifiable sources) is optimal for minimising annoyance, and combining aircraft noise with other transport sources exacerbates annoyance, whereas combining it with natural or subtle background sounds may indirectly mitigate negative perception.

3.65 **Rogers et al** published their report on the science of soundscapes, with a summary of the evidence base from the UK acoustics community. This report summarises the current scientific evidence supporting the soundscape approach. It was prepared in response to questions from the UK House of Lords Science and Technology Committee regarding the health effects of noise and the role of soundscape in future policy.

3.66 The report brings together academic literature, policy developments, and real-world case studies demonstrating practical applications of soundscape approaches and suggests that the evidence base for soundscape science is now substantial and mature. Positive sounds (e.g., nature, water, birdsong) can support mental health and wellbeing, and traditional noise control (focused solely on reducing harmful exposure) captures only "half the opportunity." It is argued that soundscape approaches can guide healthier and more regenerative urban design.

3.67 The report highlights four core mechanisms by which soundscapes improve health:

i. Positive natural sounds benefit mental restoration.

ii. Quietness is not necessarily optimal. Better outcomes often come from rich, positive sound environments.

iii. Natural sounds help mask intrusive man-made noise psychologically.

iv. Subjective end-user perception is crucial in design.

3.68 Although the report is not solely about aircraft noise, it contains several significant aircraft-noise-related findings, especially in how soundscape frameworks can improve aviation noise management. The report emphasises that transport noise, including aircraft, is usually approached reactively, with mitigation strategies employed after impacts occur. This is identified as a key limitation in traditional policy. The soundscape approach seeks to address this by prioritising contextual, perceptual, and positive-sound-integration strategies rather than relying only on decibel reduction.

3.69 One of the major case studies included was from Gatwick Airport, which describes a transdisciplinary soundscape framework to support the Fair and Equitable Distribution (FED) of aircraft. This study integrated acoustics, psychoacoustics, air traffic management, health, psychology, and community engagement, and developed the first soundscape-based method for assessing distribution options for aircraft routes. The study demonstrated that aircraft noise management benefits from considering contextual and perceptual factors, not only noise exposure metrics. The authors propose this as a model that can be applied at other airports worldwide.

3.70 The UN Frontiers Report is also referenced by Rogers et al, which discusses the need to move beyond "noise = nuisance" for aviation. The UN report highlights that policymakers often treat noise only as discomfort, especially transport noise such as aviation. It calls for broadening the approach to include positive soundscapes, integrating green infrastructure to mitigate transport noise (including aircraft) and the early consideration of aviation noise effects during planning, suggesting that aircraft noise must be managed in a wider ecological and perceptual framework.

3.71 Rogers et al discuss substantial evidence that natural sounds, including vegetation and water features can help psychologically mask intrusive noise sources like aircraft, with the inclusion of tree belts and green buffers, vegetated noise barriers and quiet urban parks offering respite. Although these measures do not silence aircraft, they improve perceived soundscape quality, helping reduce annoyance and improve wellbeing.

3.72 **Lavia et al** presented the preliminary findings of a PhD research project examining how non-acoustic factors (NAFs) shape stakeholder perceptions, engagement effectiveness, and wellbeing in the context of UK airport expansion projects. The study applied ISO soundscape standards, which emphasise assessing sound as perceived in context, rather than solely through conventional noise metrics. The rationale for the study was that soundscape-based planning can improve both community wellbeing and engagement outcomes if planners understand NAFs, such as trust in authorities, communication quality, perceived control, and emotional response in relation to how people react to sound, especially aviation noise.

3.73 The EU ANIMA project is cited within the report. It found that the major NAFs driving aircraft noise annoyance are attitude to the source, capacity to influence (voice), perceived control, and trust in authorities.

3.74 The study used constructivist grounded theory[1], based on 1:1 interviews with aviation experts, planners, engagement practitioners, and affected residents. From these interviews, the author developed a preliminary conceptual model linking soundscape factors, perceived control, and engagement effectiveness.

3.75 The findings indicated that NAFs strongly influenced stakeholder responses. Participants consistently linked their reactions to aviation noise with:

- communication quality
- trust in the process
- clarity and honesty of information
- policy complexity
- sense of agency and influence
- fairness of the engagement process

3.76 These factors were found to explain community responses beyond what is measurable using sound levels alone. The report emphasises that perceived control, a stakeholder's belief that they can influence outcomes, strongly shapes annoyance responses, willingness to participate in consultations, trust in airport operators and long-term relationships between communities and the aviation industry. A lack of perceived control increases frustration, distrust, and resistance to airport expansion.

3.77 The authors also found that communication quality is more important than communication quantity. Participants stressed that too much data overwhelms

[1] a qualitative research method that assumes reality is socially constructed and subjective, rather than objectively discovered

people, insufficient or badly timed communication worsens distrust, too much technical language feels exclusionary and that meaningful, relevant communication serves to build trust.

3.78 The report argues that soundscape planning addresses both health protection (noise mitigation) and health promotion (creating beneficial sound environments). It can complement noise metrics by incorporating community expectations, context, and experience, and may enable more sustainable and widely accepted airport-related developments.

3.79 The research ultimately aims to produce a standardised soundscape-based engagement framework that can be used not only for UK airports but also for other major infrastructure projects where noise and community acceptance intersect.

3.80 **Brown's** 2014 paper explains how soundscape planning can complement, rather than replace traditional environmental noise management. It is argued that while environmental noise management treats sound as a waste product to be reduced, the soundscape approach treats sound as a resource that can contribute positively to human wellbeing, place identity, and environmental quality. Soundscape planning therefore expands the toolkit for acoustic professionals by incorporating human perception, contextual understanding, and desired sound qualities, not simply decibel-based limits.

3.81 The paper systematically contrasted the two approaches across:

- sound sources of interest
- human responses and outcomes
- measurement techniques
- mapping methodologies
- planning and design objectives

3.82 The paper examined the distinction between noise management and soundscape planning. Environmental noise management typically focuses on reducing unwanted sounds (e.g., transport, machinery). This approach sees sound as a "waste" to be controlled, and is guided by objective metrics (e.g., L_{Aeq}) and exposure thresholds. Generally, this approach focuses on negative outcomes such as annoyance, sleep disturbance, and cognitive interference.

3.83 Soundscape planning treats sound as a resource that may provide value (tranquillity, excitement, cultural meaning, safety). This approach focuses on wanted sounds and ensuring they remain audible above unwanted ones. There is an emphasis on perceptual, contextual, and experiential outcomes.

3.84 The paper discussed and critiques reliance on integrated noise metrics (e.g., L_{eq}), and suggests that they mask contributions of different sources, and poorly predict human soundscape preference. The author argues that sound identification, source prominence, and semantic meaning are more important for perceived quality. Alternative measures (e.g., sharpness, roughness, “percent time audible”) were discussed, but the paper highlights the need for perceptual approaches.

3.85 The author explains that environmental noise maps focus mainly on road traffic noise; aircraft and industrial noise occupy smaller spatial areas but still dominate local exposure. The paper recommends supplementing noise maps with the mapping of preferred natural and human sounds, mapping based on source categories, and the use of indicators such as “percent time audible” or “time above natural ambient.” It is suggested that this helps describe the relative presence of wanted versus unwanted sounds. The paper concluded that combining both approaches provides a more holistic, culturally relevant, and context-sensitive management of the outdoor acoustic environment.

3.86 **Williams et al** investigated whether biophysiological responses (EEG, galvanic skin response (GSR), heart-rate variability (HRV)) can serve as measurable indicators of perceived noise annoyance in response to reproduced environmental soundscapes. The study explored whether acoustic characteristics, combined with physiological responses, could help predict annoyance more objectively.

3.87 The experiment used recordings of various urban and transport soundscapes, including aircraft noise, high-speed trains, trams, construction noise, highways, and urban traffic. Participants (n = 37) rated perceived annoyance on an 11-point scale after hearing each 30 second recording, while biometric data was recorded. Self-rated noise sensitivity was also provided.

3.88 The results indicated that participants found construction breaker and tram curving (wheel squeal) the most annoying noises, urban traffic the least annoying, and aircraft noise moderately annoying (mean rating 6.5 out of 10). Annoyance was strongly associated with temporal impulsiveness, and high-frequency tonal components, suggesting that the character of the noise mattered more than the context.

3.89 The biometric results varied within the study, but GSR typically spiked at the onset of each new sound. Heart-rate peaks did not directly correlate with annoyance ratings but showed slower rises for more annoying sounds. Younger participants (20-30 years) showed stronger psychophysiological responses. The authors suggested these findings indicated that biophysiological signals could help detect soundscape-driven stress responses, including those from aircraft noise.

3.90 The authors suggested that future applications of the methodology could be useful in airport soundscape analysis, aircraft noise annoyance prediction, and autonomous environmental monitoring devices. They concluded that these findings make a valuable contribution to research seeking more nuanced, perceptually grounded ways to assess and manage aircraft noise impacts, particularly relevant for aviation planning, community noise assessments, and soundscape-based regulatory approaches.

3.91 **Jiang et al** authored a report on the value of soundscapes, including for those with aircraft noise. The report addresses a central challenge in environmental acoustics: while economic appraisal tools such as Cost-Benefit Analysis (CBA) treat sound purely as a negative externality, modern soundscape science recognises that sound can also be a positive resource. The authors argue that valuation frameworks must evolve beyond noise reduction and incorporate the benefits of positive soundscapes.

3.92 The report reviews established methods for valuing noise impacts (e.g., hedonic pricing, stated preference, impact pathway methods) and evaluates their suitability for valuing soundscapes, including natural and desirable sounds. It also identifies gaps in current noise valuation practice, proposes methodological directions for future soundscape valuation studies, and outlines challenges to building a soundscape-based CBA.

3.93 The need for soundscape valuation is explained, as existing CBAs are noise-based and residential-focused, ignoring positive acoustic experiences such as natural soundscapes. The authors propose soundscape valuation is needed to capture the benefits of desired sounds and non-residential contexts, including parks, urban spaces, and public space. The Welsh Government's inclusion of soundscape in its Noise and Soundscape Action Plan (2018-2023) is cited as evidence of a definite shift in approach.

3.94 The report outlines the typical methods for noise valuation:

- Hedonic pricing (HP) uses house prices to infer noise values. It is widely used for road and aircraft noise, but results vary significantly. The report highlights the wide range in Noise Sensitivity Depreciation Index (NSDI) for aircraft noise, from 0% to 2.3% per dB.
- Stated preference (SP) includes contingent valuation and stated choice methods. A meta-analysis cited in the paper found per-dB values for road and aircraft noise of £33.32 (<55 dB), £66.06 (55-64 dB), and £126.35 (>65 dB) per household per year (2010 prices).
- Impact pathway method estimates the health and wellbeing effects of noise exposure (annoyance, sleep disturbance, cardiovascular disease etc.) and includes aviation noise as part of transportation noise assessments.

- Life satisfaction approach uses self-reported wellbeing to infer noise costs. Measures the contribution to life satisfaction, compared to the contribution of income.
- Natural capital/ecosystem services highlights the value of natural soundscapes, which may be degraded by transport noise (including aircraft overflights).
- Travel cost method and mitigation cost approaches are less commonly applied to noise, but potentially relevant for valuing unique soundscapes or protected quiet areas.

3.95 The authors explain the limitations of current noise valuation practice, whereby positive sounds and soundscape benefits are omitted. Economic valuations overwhelmingly examine noise impacts only at homes, not in public or natural environments, which means that major impacts of noise, including aircraft noise, in parks, tourist destinations, or public places are not captured in CBA. The current methods do not reflect the shift from “noise as pollution” to “sound as resource.”

3.96 The challenges for developing soundscape valuation are discussed, such as the need for soundscape metrics that link perceptual experience with acoustic and contextual factors. Soundscape mapping must capture not only noise levels but also the qualities of wanted sounds. Metrics must be standardised for integration in economic valuation (similar to per-dB values for noise), and existing metrics (pleasantness, eventfulness, tranquillity) were designed as outputs, not inputs, which complicates their use in valuation.

3.97 The authors concluded that developing a robust soundscape-based CBA requires new soundscape metrics, better data, and integrated valuation methods that recognise both the costs of aircraft noise and the value of soundscapes in which aircraft noise may intrude.

3.98 **Aletta et al** investigated the barriers and opportunities associated with implementing the ISO 12913 soundscape standard series, which provides internationally agreed definitions, methodologies, and frameworks for soundscape research and practice. The authors identify key obstacles faced by National Standards Bodies (NSBs) and soundscape stakeholders and propose strategies to promote broader global adoption of the soundscape approach.

3.99 The study uses semi-structured interviews with NSB representatives and a focus group with international soundscape experts to understand technical, organisational, cultural, and operational challenges that influence the uptake of soundscape standards. The aim was to support the development of healthier sound environments by ensuring the ISO 12913 series is used effectively and internationally.

3.100 The ISO 12913 series was launched to create a standardised, interdisciplinary approach to soundscape assessment and design, making research and practice more coherent and comparable across countries. The series includes:

- Part 1 (2014): Definition and conceptual framework
- Part 2 (2018): Data collection and reporting
- Part 3 (2019): Data analysis
- Part 4: Soundscape design and intervention methods

3.101 It is explained that despite the value of the standards, implementation has been uneven across countries, prompting the authors' investigation into underlying causes.

3.102 The study comprises two parts. Firstly, interviews with NSB representatives were conducted, resulting in twelve interviews across nine countries. The interviews examined processes for appointing experts, awareness of ISO 12913, barriers to engagement, and national priorities and resource allocation.

3.103 The second part involved the use of focus groups with soundscape experts. 23 experts were invited; 12 accepted, 9 participated live, and 3 were interviewed separately. Participants represented industry, academia, NGOs, policy sectors, and multiple world regions. Three main questions explored:

- What prevents engagement with ISO 12913?
- How can these barriers be removed?
- How can the standards make wider impacts?

3.104 The main barriers identified by NSBs were limited awareness and literacy. Many NSB representatives were unfamiliar with ISO 12913 or with the soundscape concept itself, especially in countries where acoustics-related committees are small or non-existent. Resource constraints and a lack of national interest were also given as possible barriers, along with language and time-zone challenges which may hinder participation in international working groups. Soundscape experts highlighted the lack of practical examples, i.e., there are relatively few case studies of soundscape standards in practice, making it harder for policymakers to understand their value. They also stated the dominance of traditional noise metrics (decibel-based), different interpretations of soundscape meaning, and a need for cross-disciplinary collaboration with public health, urban design, transport planning, and environmental policy as barriers.

3.105 The authors propose that addressing these barriers requires improved training, clearer communication, and interdisciplinary collaboration, and active international support. They state that broader engagement with ISO 12913 can meaningfully contribute to healthier, more sustainable sound environments.

Soundscape research and Covid-19

3.106 The Covid-19 pandemic and resulting lockdowns afforded a unique opportunity to examine soundscapes with dramatically reduced transportation noise, including that from aircraft. This section includes findings from research conducted during that period.

3.107 **Hasegawa and Lau** published their qualitative and quantitative synthesis of the impacts of COVID-19 on soundscapes. This was a systematic review and meta-analysis examining 119 studies on how the COVID-19 pandemic influenced soundscapes, including changes in auditory perception, noise levels, and related health/wellbeing consequences. The study examined qualitative evidence on people's perceptions of soundscape changes; and quantitative noise data from 31 studies (148 samples), analysing noise level reductions. The study contains several important observations relating directly to aircraft noise, both quantitative and perceptual.

3.108 Firstly, reductions in aircraft movements led to substantial decreases in aircraft noise levels. Examples cited in the review included Montano & Gushiken (2020) (Lima), Vogiatzis et al. (2020) (Athens International Airport), Amoatey et al. (2021) (Oman), with a mean reduction of aircraft noise of −7.9 dBA (SD = 2.58). The authors caution that the sample size was small (three studies), and this reduction is large compared to many road traffic-related reductions, confirming aviation was one of the most affected sources. The study highlights evidence of measurable cardiovascular benefits associated with decreased aircraft noise exposure. A cited study by Wojciechowska et al., 2022, found a substantial decrease in adverse cardiovascular events during lockdown due to reduced aircraft noise. In Oman, aircraft noise annoyance decreased from 84% pre-pandemic to 41% during the pandemic.

3.109 Lockdown reductions in flights were found to contribute to greater audibility of natural soundscapes (birds, wind, etc.), and higher perceived restorative quality of outdoor environments. In the meta-analysis, noise reductions related to road traffic were sometimes insensitive to lockdown severity. In contrast, reductions linked to aircraft noise tracked more closely with reductions in human mobility, flight cancellations, and border closures. Although the sample size was small, aircraft noise exhibited one of the largest average reductions across all source types evaluated.

3.110 **Qu et al** investigated how soundscape characteristics and subjective (non-acoustic) factors influenced residents' evaluation of aircraft noise in communities located directly under flight paths near Shenzhen Bao'an International Airport. The study was conducted during the COVID-19 pandemic when community lockdowns intensified residents' reliance on local outdoor spaces. The research explores how natural sounds, personal attitudes, and psychological factors can moderate annoyance responses to aircraft noise.

3.111 The authors combined field noise measurements with paper questionnaires (n = 186) across three residential communities exposed to comparable aircraft noise levels but with differing soundscape features (e.g., fountains, waterfalls, birdsong). Aircraft noise was found to be highly noticeable and widely annoying in this sample, with 97% of respondents reporting they noticed aircraft noise in public spaces. 88% reported being annoyed, and 26% were highly annoyed (HA%), despite similar noise exposures of 63-68 dB L_{dn} across sites.

3.112 Although the study sites had similar aircraft noise exposure levels, annoyance differed across communities because of variation in restorative natural sounds. Sites with birdsong or fountain/waterfall sounds exhibited lower degrees of highly-annoyed respondents (17-24% compared to 37%), and higher ratings for “pleasant,” “natural,” and “predictable” soundscapes. Natural sounds were found to moderate annoyance, likely via masking or restorative mechanisms.

3.113 Regression analysis suggested annoyance was significantly higher among newer residents, property renters or temporary residents and those people who used public spaces more frequently. These findings suggested that increased place attachment and familiarity may reduce sensitivity, while frequent exposure in outdoor spaces amplifies annoyance.

3.114 Annoyance increased significantly with noise sensitivity, fear of flight, infrequent air travel (frequent flyers were less annoyed), female gender, older age, lower income, lower education level (high school or undergraduate level). The authors explain that this confirms the influential role of non-acoustic factors well documented in aircraft-noise literature.

3.115 The study found that while noise level (SPL) alone was not directly associated with health, annoyance was a significant predictor of poor health. Each 1-point increase in annoyance on the 0–10 annoyance scale increased the odds of self-reported poor health OR = 1.36, p = 0.017.

3.116 It was concluded that the study provides strong evidence that aircraft noise annoyance is shaped by much more than noise levels, including community soundscape characteristics, subjective attitudes and psychological traits, use of public spaces and sociodemographic factors. Natural sounds (birdsong, fountains, waterfalls) can significantly reduce annoyance and improve perceived soundscape quality. High annoyance is associated with poorer self-reported health, and vulnerable groups (older adults, frequent space users, people in poor health) may need special consideration.

3.117 The authors argue for integrating soundscape design, including natural sound interventions, into aircraft noise management to help mitigate negative impacts. They suggest that noise policy should broaden beyond decibel limits to include soundscape quality and non-acoustic factors, and community engagement

should consider personal attitudes, fears, and sensitivities to better address residents' concerns.

Future directions of soundscape research

3.118 **Kang** published a high-level reflection on five decades of soundscape research and practice, describing the transition from traditional noise-control engineering to a more holistic, perceptually grounded soundscape approach. Historically, environmental acoustics focused on noise reduction. Over the last several decades, research has increasingly recognised that reducing decibel levels alone does not guarantee better quality of life, and only around 30% of noise annoyance can be explained by physical sound level metrics. The type of sound, context in which it is experienced, and user characteristics strongly shape perceptions around sound. Kang explains that this motivated a transition towards designing positive sound environments.

3.119 The paper provides an outline of historical soundscape research. R. Murray Schafer's early soundscape work in the 1970s established the conceptual foundation by studying how people experience sound in real places, including longitudinal "village soundscape" comparisons. This was followed by the creation of the World Forum for Acoustic Ecology (WFAE) in 1993. The EU Environmental Noise Directive (END) generated interest in preserving "quiet areas," prompting soundscape methods to complement conventional noise mapping.

3.120 The current advances in soundscape research are discussed:

- Understanding and exchanging. Includes psychological evaluation of soundscapes across many contexts (streets, parks, stations, schools, heritage sites, etc.). Studying a wide variety of sound sources including aircraft noise, industrial noise, road traffic, wind turbines, amplified music, and natural sounds. Exploring interactions with emotion, attention, behaviour, social relations, and cultural interpretation.
- Collecting and documenting. Development of large, contextualised databases, and the need for publicly available, harmonised datasets across cities.
- Harmonising and standardising. Development of perceptual metrics beyond decibels, cross-cultural measurement protocols, and emerging projects such as Soundscape Indices (SSID) to integrate perceptual, psychoacoustic, cognitive, and physiological variables.
- Creating and designing. Involves design guidelines, mapping tools, auralisation tools for public participation, and frameworks for soundscape planning in parks, open spaces, and heritage environments.
- Outreaching. Soundscape increasingly informs national noise policy (e.g., UK, Wales), public engagement, and conservation of acoustic heritage.

3.121 The paper discusses the challenges for the next fifty years and describes the growth of sensor networks that facilitate real-time soundscape monitoring. An increase in more adaptable and personalised sound environments is expected. Covid-19 lockdowns showed that quieter environments can paradoxically increase annoyance, highlighting the need to design soundscapes, not only reduce noise.

3.122 Climate change challenges leading to changes in biodiversity, weather patterns, and physical environments will alter both sound sources and sound preferences in years to come. It is also expected that an increase in home working and hybrid work patterns will increase the importance of indoor soundscape quality and reshape expectations in residential environments.

3.123 Aircraft noise is recognised as a distinctive and dominant man-made noise source requiring perceptual understanding beyond physical level metrics. The author stresses that sound level explains only 30% of annoyance responses, including for aircraft noise, and that contextual and perceptual variables are essential for understanding aircraft noise impacts. Evaluation frameworks increasingly assess soundscape quality in multi-source environments, where aircraft noise interacts with other sounds (e.g., natural sounds, voices, traffic). The soundscape field acknowledges aircraft noise as a major contributor to negative urban soundscapes and a key target for perceptual mitigation.

Chapter 4

Summary

4.1 This update to ERCD 1207 has summarised key research published since 2012 on aircraft noise, tranquillity, and the role of soundscape science. The review indicates that tranquillity, defined as calmness, peace, and freedom from disturbance, is strongly linked to exposure to natural environments, and that aircraft noise can be a significant disruptor of tranquillity, particularly in rural, green, or otherwise quiet settings.

4.2 The findings in this report confirm that tranquillity is a critical environmental and public health resource. Traditional noise metrics capture only part of the impact from transportation noise, and soundscape science offers practical tools for understanding, managing, and mitigating the perceptual and experiential dimensions of aircraft noise.

4.3 Tranquil areas provide measurable health benefits, including better psychological wellbeing, lower stress, and improved quality of life. Evidence suggests that aircraft noise undermines these benefits through annoyance, disruption of restorative processes, and changes to perceived environmental quality.

4.4 The report has discussed the need for protection of quiet and tranquil areas, the integration of soundscape principles into airspace design and master planning, use of non-acoustic factors in assessment frameworks, improved community engagement, and the importance of the expansion of research into context-based and restorative soundscapes.

4.5 The evidence base for aircraft noise and tranquillity is a growing area, with soundscape approaches becoming increasingly desirable for effective modern noise management.

Chapter 5
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