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REVISING A NATIONAL STANDARD ON RESIDENTIAL ACOUSTIC DESIGN: SCIENCE, EMBEDDED PRACTICES, HEARTS AND MINDS

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ABSTRACT

In 2024, Harvie-Clark and Fenech published a set of proposals for updating a British Standard widely used for its residential acoustic design guidance. The proposals suggested a shift from the current approach targeting fixed averaged internal sound levels, irrespective of the sound source. The proposals put stronger emphasis on external sound levels, by assigning facades into sound exposure categories (SEC), informed by the synthesis of epidemiological evidence gathered over the past two decades. The building envelope is then designed with equivalent levels of sound insulation corresponding to equivalent adverse effects from noise, and a holistic consideration of indoor environmental quality. The proposals were accompanied by an extensive programme of dissemination events in the UK. This paper gives an overview of the feedback gathered from these events - with a particular focus on the aspects that were least and most contentious. Some of the areas covered include: differences between the WHO 1999 vs 2018 Guidelines, the relevance of external sound levels to population health, the additional value and underpinning evidence associated with criteria for noise events, specifying a facade acoustic performance vs internal levels, and setting criteria for noise sources other than transport.

Keywords: residential acoustic design, national standards, acoustic regulations.

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1. INTRODUCTION

The British Standard BS 8233 "Guidance on sound insulation and noise reduction for buildings," [1] provides guidance for the control of noise in and around buildings. It is applicable to the design of new buildings, or refurbished buildings undergoing a change of use within the UK. In this paper we are focusing on the requirements relevant to the acoustic design of new residential development. The standard was last updated in 2014 and is currently undergoing a revision. In 2024, Harvie-Clark and Fenech [2] published proposals that aimed to align the acoustic criteria for residential development with the body of evidence that has been published in the last two decades, including the 2018 WHO Environmental Noise Guidelines for the European region [3]. In brief, the proposals:

a) Introduced the concept of noise source-specific "Sound Exposure Categories", defined by the external sound levels corresponding to specific health outcomes (i.e. percentage of population highly annoyed or highly sleep disturbed);
b) Specified target internal conditions in terms of a facade sound insulation performance, with an equivalent performance requirement for equivalent source-dependent health burden; and
c) Suggested guidance whether opening windows can be used to mitigate overheating, depending on the corresponding Sound Exposure Category.

The rationale for point (a) is the strengthening epidemiological evidence showing that the adverse health risk increases with external sound level, and the availability of exposure response relationships allows the increased risk above a certain threshold to be quantified. The rationale for point (b) is that for a given long-term averaged sound level, aircraft and railway noise are more annoying and sleep disturbing than road traffic noise - this could be partly explained by the higher instantaneous sound levels during aircraft flyovers and train pass-bys for typical exposure situations. The rationale for point (c) is to emphasize the need for a holistic design of a healthy indoor environment that takes into account safe temperatures, noting the increased risk of overheating from a changing climate[1].

To encourage debate on these proposals, Harvie-Clark and Fenech participated in an extensive programme of dissemination events between September 2024 and March 2025, both in-person and online, targeting members of relevant professional and trade bodies in the UK (Institute of Acoustics (IOA), the Association of Noise Consultants (ANC) and the Chartered Institute of Environmental Health (CIEH)). These events sparked strong interest[2] and a very active debate, with practitioners expressing a broad range of views. In general, there was good agreement with the underpinning principles of the proposed changes during these events (see Annex A). However the discourse outside the events was largely shaped by those that had strong opposing views, which even led to requests for stopping the proposals from going out for a public consultation. In this paper, we present some of the salient points from the debate that has taken place to date.

2. RELEVANCE OF OUTDOOR VS INDOOR SOUND LEVELS TO PUBLIC HEALTH

A letter to the editor [5] published in a bimonthly magazine of the Institute of Acoustics, signed by 33 experienced acousticians, raised important questions about the proposed approach to include external noise levels as key design criteria. Their concern can be summarised by the following extract from the letter [5]:

"To align with public health research the proposal is to assess and control noise exposure via the external sound levels, under the mistaken assumption that this alignment with the evidence base justifies a departure from controlling internal levels.

I don't think anyone has ever actually suggested that the community health impacts from environmental sound on residents in buildings is predicated more on the noise levels outside the buildings in which they are exposed than those they experience internally. It is just much more difficult to do large scale studies on actual internal levels in comparison with the convenience of large-scale noise mapping. Hence all the recent studies refer to external levels as a proxy.

By definition, a proxy is not the parameter we are trying to control to the benefit of residents to deliver suitable internal living conditions. It's like trying to drive a car looking only at the sat-nav screen! This lack of precision – the failure to target the parameter itself rather than the more convenient proxy is uniquely problematic in relation to exposure of individuals to environmental sound."

Similar arguments were made in a position statement published on the website of the Chartered Institute of Environmental Health [6], where it was argued that:

"If we are interested in the design of new homes to provide good or reasonable living conditions indoors then we need to identify the best evidence that relates to internal noise conditions."

Harvie-Clark and Fenech published a response to these points [7]. The response drew on three fundamental concepts that have defined noise and health theory for many decades:

i. Noise is a psychosocial stressor, i.e. '*an environmental factor interacting with social and cultural factors to influence the mind and behaviour*' [8]. Within this framework, noise exposure 'at home' is not limited to the sound levels inside the physical space enclosed within a building envelope. It also covers any outdoor spaces that residents consider part of their home. This is also consistent with how the international standard for measuring noise annoyance [9] defines the wording 'at home' to capture inside the home or outdoors at home, including balconies, gardens, etc.

ii. The mechanistic evidence on the relationship between chronic noise exposure and chronic health outcomes supports a direct pathway and an indirect pathway [3,10]. The indirect (psychological) pathway is mediated by cognitive and emotional responses to the personal experience of the noise, which is not limited to the sound levels experienced when inside the home.

[1] For example, a report by the Climate Change Committee [4] notes that "*Increases in temperature have been linked with an increase in the death rate (particularly amongst older people) across the UK, including in recent heatwaves in every year from 2018 to 2021. Recent estimates suggest that around a fifth of homes in the UK are already overheating in summers today*" and "*Climate projections suggest that a 'hot' summer such as 2018 will become the average summer by 2050, even with deep cuts in global greenhouse gas emissions. The combination of increasing hot weather, and an ageing population, means that heat-related deaths may treble without further adaptation actions.*"

[2] One lunchtime webinar organized specifically for introducing the proposals hit the participants limit of the IOA's Zoom account (500) and was one of the most attended IOA event in its history.

iii. A dwelling is not just a physical structure – it represents a place where people call home [11]. The places where people live have a significant impact on their mental and physical health [12]. When residents feel a deep connection to their place of residence, they are more likely to be satisfied with their living conditions. This relationship is influenced by various factors, including the quality of the physical environment, social interactions and the availability of amenities. Noise has been shown to interact with some of these factors [13, 14]. Socio-acoustic studies from Norway found that the noise levels in the immediate neighbourhood of a home can affect residential noise annoyance, with a similar effect on both outdoor and indoor noise annoyance [15].

To support these theoretical concepts, Fenech and Harvie-Clark drew on evidence from two studies in Sweden [16, 17] that investigated the influence of the external sound environment on disturbances inside the dwelling. For example, in [17], for the same internal averaged noise levels, disturbances to communication, listening to TV/radio, concentration and relaxation were consistently higher with high external levels (windows closed) than with a quieter external environment (windows open). Similar observations were made for sleep disturbance. Other studies on noise annoyance investigated differences between outdoor and indoor annoyance (see for example [18]) and indoor annoyance with windows open and closed (see for example [19]). These studies show that both outdoor annoyance, and indoor annoyance with windows open are important contributors to the overall annoyance reactions and therefore support the relevance of both the external and internal sound exposure at home.

3. RELEVANCE OF WHO ENVIRONMENTAL NOISE GUIDELINES (2018) FOR RESIDENTIAL ACOUSTIC DESIGN

The CIEH statement included the following arguments [6]:
"*The recommendations made in the WHO Community Noise Guidelines were derived using evidence relevant to internal noise conditions, including interference with communication and sleep disturbance effects. It was recognised that the maximum noise level was best correlated with effects on sleep and that is the reason why the recommendations for the protection of sleep inside dwellings included the 45 dB L_{Amax} criterion. In 2018 the WHO reviewed the available scientific evidence and published the Environmental Noise Guidelines European Region 2018* [ENG2018]. *It concluded that:*
"The current environmental noise guidelines for the European Region supersede the CNG [1999 WHO guidelines for community noise] from 1999. Nevertheless, the GDG [Guideline Development Group] recommends that all 1999 CNG ***indoor guideline values*** *and any values not covered by the current guidelines (such as industrial noise and shopping areas)* ***should remain valid****." (Our emphasis)."*

The CIEH statement went on to suggest that the proposals by Harvie-Clark and Fenech departed from WHO recommendations. The statement did not mention that the ENG2018 explicitly state that "*The* [2018] *guidelines are source specific and not environment specific. They therefore cover all settings where people spend a significant portion of their time, such as residences …*". The CIEH statement also did not mention that the 1999 CNG [20] guideline values for residential settings were expressed as both external and internal levels.

In response, Fenech and Stansfeld [21] published an article to clarify the relationship between the WHO 1999 CNG and ENG2018. In summary, Fenech and Stansfeld argue:
"When referring to WHO guidelines to set criteria for residential settings (dwellings) exposed to transport noise, the main reference should be to the WHO Environmental Noise Guidelines for the European Region (ENG2018), because they are the most up-to-date guidelines. Additional consideration can be given to the indoor guideline values in the Guidelines for Community Noise [CNG (1999)], but only if this is done in conjunction with the external guidelines in the ENG2018 and taking into account the source-specific characteristics of the sound (e.g. intermittency, low frequency content, etc). In writing the ENG2018 it was clear that the indoor guidelines from the CNG (1999) could not and should not be quoted or used in isolation."

4. CAN HIGH FAÇADE SOUND INSULATION PERFORMANCE LEAD TO "COMPROMISED LIVING CONDITIONS"?

The letter to the editor by Clarke and Fiumicelli [5] appeared to suggest that up to a certain level, transport noise ingress in buildings with windows closed can have beneficial health effects:
"*If, for example, rather than achieving internal conditions at night of 30dB $L_{Aeq,8hr}$ with L_{max} levels in the low 40s in two apartment buildings, we get one building with 20 $L_{Aeq,8hr}$ (L_{max} in the low 30s) and one building at 40 $L_{Aeq,8hr}$*

(L_{max} in the low 50s) then BOTH sets of residents have dramatically compromised living conditions, due to annoyance and sleep disturbance in the under-attenuated case and high levels of neighbour noise disturbance in the over-attenuated building."

The CIEH statement [6] also included the following statement:

"The proposed revisions to BS8233 place too much emphasis on façade insulation and overheating. This appears to be fundamentally at odds with the guidance contained in the ProPG[3]".

To our knowledge, there is no robust scientific evidence demonstrating that lower internal sound levels due to higher façade sound insulation leads to 'dramatically compromised living conditions' or increased neighbour noise disturbance. While anecdotal reports of increased sensitivity to neighbour noise in quieter environments exist, these have not been substantiated by systematic studies. It is not clear how noise from discrete car/train pass-bys or aircraft flyovers that averages to an internal level of 30dB $L_{Aeq,8hr}$ can be effective at reducing disturbance from an unpredictable and intermittent source such as neighbour noise. External anthropogenic noise ingress with windows closed should not be relied on as a sound source contributing to a positive internal soundscape in homes, because it is completely out of the control of the building occupant. Research by Torresin et al [22] demonstrated the importance of control over one's environment to achieve an ideal indoor soundscape for work and relaxation. We argue that neighbour noise disturbance should be managed by appropriate levels of sound insulation between dwellings and, if acoustic masking is necessary, this should be achieved by sources of sound that are under the full control of the building occupants.

5. THE ROLE OF MAXIMUM SOUND LEVELS IN RESIDENTIAL ACOUSTIC DESIGN

A common argument that came up at several engagement events and was noted in the CIEH statement [6], was the lack of L_{max} criteria in our original proposals, and the perceived lack of protection for sleep disturbance because of this omission.

There is clear evidence that L_{max} correlates better with short-term noise-induced physiological sleep disturbances than long-term averaged noise metrics [24]. However the relationship between single-event noise indicators and long-term health outcomes at the population level remains tentative [3]. Simplistic criteria, such as indoor sound pressure levels not to exceed approximately 45 dB L_{Amax} more than 10–15 times per night, are based on studies from the 1970s-80s [20], and such criteria can be expressed in terms of an energy equivalent level such as $L_{Aeq,8hr}$ [20]. Basner et al. [23] proposed a physiological noise effects criterion for the protection against adverse effects of nocturnal aircraft noise. Applying this criterion requires detailed knowledge of all the noise events and their respective L_{max} throughout the night. Such an approach would be feasible and appropriate to inform decisions on changes around transport hubs such as airports (e.g. new runway, airspace changes or changes to night flights), given that aircraft noise modelling software can predict L_{max} data. However, applying this approach to new residential acoustic design would require comprehensive new guidance on how to obtain representative internal L_{max} distributions throughout the entire night period[4]. Instead, our proposals [2] were derived from source-specific self-reported sleep disturbance evidence, in accordance with the WHO 2018 recommendations [3]. Self-reported sleep disturbance responses take into account additional dimensions of sleep disturbance, such as problems falling asleep at the beginning of the night and falling back to sleep after a conscious awakening [24].

5.1 Practitioners' views on maximum levels

In a questionnaire ran at some of the outreach events (see Annex A), participants were asked to state to what extent they agreed with these five statements (shown from left to right in Fig. 1):

i. I am comfortable specifying and/or complying with L_{max} criteria.
ii. There is good quality evidence linking L_{max} criteria to long term health outcomes.
iii. Including additional L_{max} criteria in BS 8233 will add value to residential acoustic design.
iv. BS 8233 should include L_{max} criteria for all situations.
v. BS 8233 should include L_{max} criteria only for specific situations.

Statements *ii,iv* and *v* invited additional free text comments. Referring to Fig. 1, practitioners were generally comfortable specifying and/or complying with L_{max}

[3] The Professional Practice Guidance on Planning and Noise (ProPG) was published in 2017 to provide practitioners with guidance on a recommended approach to the management of noise within the planning system in England. It was co-produced by the CIEH, IOA and ANC.

[4] In the UK, current national noise modelling tools for road and conventional railway noise do not output L_{max} data.

criteria, despite responses to the second question being mostly neutral or disagreeing that "There is good quality evidence linking L_{max} criteria to long term health outcomes". Most respondents strongly agreed, agreed or were neutral in response to the statement that "*Including additional L_{max} criteria in BS 8233 will add value to residential acoustic design"*. Most respondents were neutral, however, in response to the final two statements suggesting that BS 8233 should include L_{max} criteria for all situations / only for specific situations.

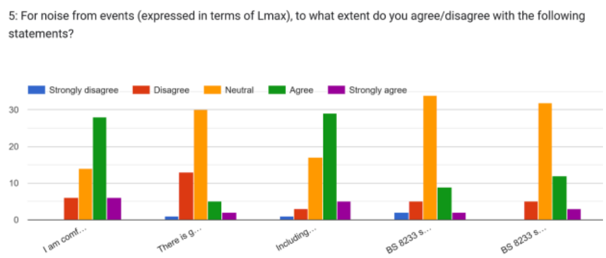

Figure 1 Survey question on noise events - see text for the complete text of the five options.

The following sections summarize the free text responses, categorized under six themes.

5.1.1 Practical Utility Despite Evidential Limitations

A prominent theme in the responses was the suggestion of the practical utility of L_{max} in real-world applications, despite acknowledged limitations in its evidential basis. Many respondents consider L_{max} "well understood" and effective for "giving a resident an appropriate environment", despite the lack of evidence linking this metric with long term health outcomes.

Several comments suggested that L_{max} provides valuable contextual information that benefits "all stakeholders". Respondents highlighted specific applications where L_{max} is particularly useful, such as "nighttime economy in urban areas" and "where residential is located above or adjacent to a significant sound source".

5.1.2 Concern About Evidence Gap vs. Practical Need

Responses acknowledged the tension between the lack of robust evidence linking L_{max} to health outcomes and their perception of its practical importance. Several comments acknowledge the evidence gap we had presented: "You've presented the case that there is insufficient health evidence". However, this was frequently countered with caution: "Lack of evidence of correlation isn't evidence of a lack of correlation". Some respondents remained hesitant about abandoning L_{max}: "not convinced yet that we should be disregarding L_{max} levels altogether".

5.1.3 Source-Specific Applications

Some comments suggested that L_{max} may be more relevant for certain noise sources than others. Specific mentions of "ambulance and police alarm", "lift noise, plant noise," and "wind farms", for example. Several respondents suggested that while our approach for "road, rail, air traffic sources" may be appropriate, guidance is still needed "for other sources". Entertainment venues, "intermittent disturbing noise sources running through the night," and impulsive sounds were highlighted as requiring specific consideration. We acknowledge these arguments, and changes were made to the BS8233 proposals to state that an assessment of noise from events may be appropriate in certain situations.

5.1.4 Pragmatic Regulatory Concerns

Some respondents raised concerns about the practical implications of removing L_{max} criteria in regulatory contexts: "removing L_{max} altogether from BS 8233 might open the door to more unscrupulous developers/ contractors". There were concerns that without L_{max}, some stakeholders "won't pay for a more detailed approach/ or attempt to understand the health effects". There were some suggestions that L_{max} serves as a simple, understood metric that facilitates compliance checks.

5.1.5 International Context and Alternative Approaches

A few responses alluded to international perspectives and alternative approaches. Reference was made to criteria in "some other countries (primarily Australia and particularly Spain/Barcelona)", for example. There were suggestions that further research into L_{max} "ahead of the revision" would have been beneficial, and indications that a comparative analysis of different regulatory approaches might be valuable.

5.1.6 Assessment Challenges

Several comments acknowledged the practical difficulties in using L_{max} as an assessment tool. There was recognition that "L_{max} assessment is fraught with assumptions and uncertainty", and implicit acknowledgment of methodological challenges in applying L_{max} criteria consistently.

5.2 Comparing L_{max} criteria with real-world data

This thematic analysis suggests that while there is acknowledgment of the limited evidence base for L_{max}

criteria in relation to long-term health outcomes, there remains significant attachment to the metric for specific applications and contexts. The responses suggest a desire for better guidance rather than its complete removal.

We carried out simulations based on actual measurements of road traffic noise to test how our proposed internal criterion (façade sound insulation ≥ L_{den} – 32dB) compares with two L_{max} based criteria:

- less than 10 events with L_{AFmax} > 45dB (referred to as "10th highest $L_{AF,max}$ meeting 45dB") [20]; and
- less than one additional awakening per night (referred to as "1AW") [23].

The measurements consisted of 187 24hr sound level profiles, typically made at distances of up to 10m from the kerbside[5]. From each data set, we extracted the following information: L_{den}, $L_{Aeq,16hr}$, $L_{Aeq,8hr}$, and for the night time period: highest $L_{AF,max,8hr}$, 10th highest $L_{AF,max,2\ min}$ and the complete set of $L_{AS,max,2min}$ (i.e. 240 values for each night). We then calculated the façade reduction required to achieve the relevant criterion. The reduction required was calculated as a facade level difference, based on the A-weighted values for the indicators, and assuming a standardised road traffic spectrum[6]. The method used to determine the facade level difference to achieve the 1AW criterion internally is described in [25], using dose response functions from [24].

Figures 2 and 3 show how our original proposals (orange line: equivalent to a Class D classification in ISO/TS 19488:2021) compares to the two different L_{max}-based criteria. Individual markers represent each 24hr dataset. If a marker is above the orange line, the façade insulation requirement to meet the relevant L_{max} criterion is higher than our proposed target, and vice-versa.

Fig. 2 shows that in the majority of cases, a higher level of facade sound insulation is required to achieve less than ten events with $L_{AF,max}$ > 45 dB than to meet an internal level of 35 dB L_{den}. Fig. 3 shows that meeting 35 dB L_{den} achieves the 1AW criterion on average, and in more than 80% of cases. The mean difference between the requirement to meet the 45 dB $L_{AF,max}$ criterion and the 1AW criterion was 4.0 (± 3.2) dB, with a range from + 13 to -5 dB.

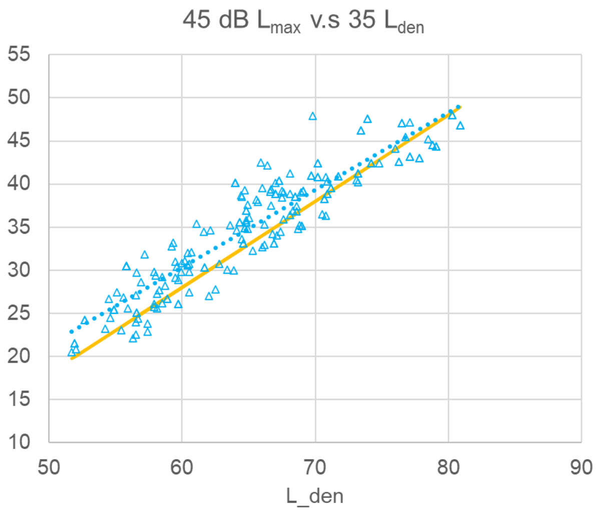

Figure 2 Facade level difference required to ensure the "10th highest $L_{AF,max,inside}$ < 45dB" criterion is met, plotted as a function of external L_{den} level. Each blue marker represents a 24hr measurement. The orange line represents the criterion in our original proposals [2].

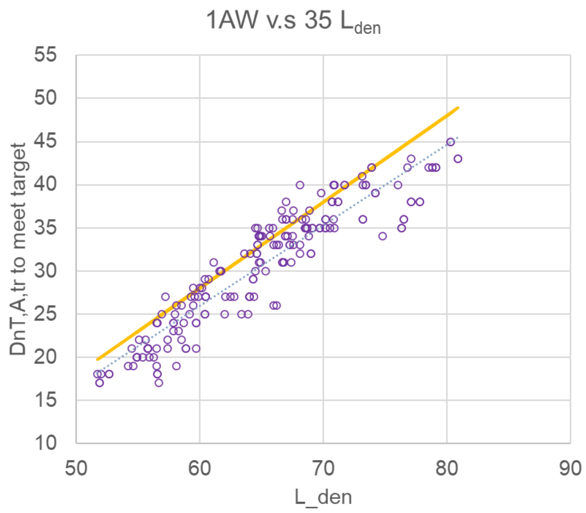

Figure 3 Facade level difference required to ensure the "1 additional awakening per night" criterion is met, plotted as a function of external L_{den} level. Each purple marker represents a 24hr measurement. The orange line represents the criterion in our original proposals [2].

[5] Further details of the measurements can be found in [26].

[6] This is a simplification, as a real facade provides different levels of A-weighted attenuation depending on the frequency content of the incoming sound field. This is particularly relevant for assessing noise from events, for which the frequency content can vary widely.

6. CHANGING THE STATUS QUO – HEARTS AND MINDS

Both the letter to the editor by Clarke and Fiumicelli and the CIEH statement argued in favour of maintaining the status quo. The former argued [5]:

The UK has a reputation for practical delivery against internal criteria. It's what we do really well. As with the delivery of sound insulation between dwellings via pre-completion testing and Robust Details, acousticians in other jurisdictions look on with envy at the UK's track record for effective delivery against measured in-situ performance.

The suggestion that we dispense with this process to align with the proxy parameter used for convenience in the broader-brush epidemiological studies is a reductive and retrograde proposition.

The CIEH statement argued [6]:

"Although the proposed revisions to the standard are based on what the authors consider to be sound scientific studies, the internal and external noise levels have been used for decades without apparent problems or challenges."

Whilst both narratives suggest that current methods work '*without apparent problems*', no evidence was provided in either instance to support these claims. However, there is evidence that current approaches are leading to problems. For example, a Quieter Road-Map published by Sustainable Aviation noted [26]:

"*The development of land near and within areas of high aircraft noise areas around airports for noise-sensitive uses, including residential development continues to be, a major challenge that many UK airports are facing. Many of the measures in the ICAO Balanced Approach are in place at UK airports and are incorporated in airport Noise Action Plans. However, the effectiveness of airport and airline noise control measures can be compromised by competing demands on the planning system to deliver residential development in noise sensitive areas, Some Local Planning Authorities have been forced to prioritise housing targets over exposure to aircraft noise. This has resulted in residential development encroaching in areas around airports that are subject to higher levels of aircraft noise."*

The CIEH statement also argued against any potential conflicts with existing guidance (ProPG), published in 2017, because "*Discrepancies between the ProPG and BS8233 could lead to confusion and hinder the promotion of design outcomes that support good health and quality of life.*" During the engagement events it was noted that there was currently no appetite within the ANC or the CIEH to revise ProPG.

Another criticism of the proposals that came up at some of the events was on the use of the L_{den} metric. Whilst we acknowledge that the L_{den} metric does not fully capture the complex relationships between sound and health, the same can be said of the other metrics in the current standard ($L_{Aeq,16hr}$ and $L_{Aeq,8hr}$). Our original proposals were expressed in terms of L_{den} to align with the large body of epidemiological evidence on sound and health. Whilst conversions between metrics are possible, these introduce additional, and in our view, unnecessary uncertainties.

7. ACKNOWLEDGMENTS

We are grateful for the extensive engagement of the UK acoustics community during the outreach events that took place since September 2024, which has led to further refinement of the proposals. We also acknowledge the constructive "check and challenge" by the BS8233 drafting panel, led by Dr. David Hiller. Special thanks to Weigang Wei, AtkinsRealis for extracting the sound data used in the L_{max} analysis. The views expressed in this article are those of the authors and are not necessarily those of UKHSA or the Department of Health and Social Care.

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9. ANNEX A – ENGAGEMENT EVENTS

The development process of British Standards of UK origin is broadly similar to that for international and European standards, although there are no voting stages. The relevant committee overseeing a standard revision is asked to give approval at two stages (for the draft to go to public consultation and for the final version to be published). Public consultation on a 'draft for public comment' is considered an essential part of the process and the responses arising from it are reviewed in the same manner as for international and European projects [28].

The engagement and dissemination events were intended to inform relevant audiences of the main proposed changes to BS 8233 in advance of the public consultation, and to provide more detailed information on the rationale and supporting evidence that informed the proposals.

During four of the events taking place between January and March 2025, we gathered feedback using two separate questionnaires. We obtained 56 and 70 responses to these questionnaires, out of an estimated 150-200 delegates. 50 – 60% of respondents were from the private sector. The majority of the non-private sector responses were from environmental health practitioners working in the public sector, who take a regulating role within the planning system in the UK.

Respondents to the questionnaire were generally supportive of our guiding principles:

- 59% agreed that current knowledge on noise and health warrants more emphasis on external sound levels, reflecting the latest WHO evidence base.
- 89% of respondents supported accounting for how different transportation sources affect health to different extents.
- 75% of respondents viewed Sound Exposure Categories as useful markers for navigating noise impacts in planning.

Concerns were raised about specifying a sound insulation performance instead of internal sound levels, and about the challenges associated with practical implementation. Further details on the survey responses can be found in [29].