# UNCERTAINTY WITHIN OUTDOOR PROPAGATION CALCULATIONS SUBMITTED TO THE ENVIRONMENT AGENCY FOR PERMIT APPLICATIONS

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## 1 INTRODUCTION

The Environment Agency's Acoustics and Air Quality Modelling and Assessment Unit (AQMAU) audits noise impact assessments (NIAs) submitted in support of environmental permit applications, on behalf of the National Permitting Service. Most permit applications are for installations or processing activities which do not yet exist. Therefore, where there is a risk of noise pollution from these sites, it is common that noise modelling software or calculation methods in line with ISO 9613-2:2024[2] are used to predict sound pressure levels at nearby sensitive receptors. These are typically used as specific sound levels as part of a predictive BS 4142:2014+A1:2019[1] assessment of industrial noise impact. Acoustic propagation calculations require the user to make a range of assumptions such as the type of ground, the number and strength of any reflections, the shape and location of obstacles etc. These assumptions need to match the real situation on site to arrive at a reliable result. These choices often have a greater effect on uncertainty than the accuracy for the method detailed in ISO 9613-2.

This paper details a review of the accuracy of propagation calculation approaches in BS 4142 assessments to quantify how these affect predicted specific sound levels at receptors. Following AQMAU observations and sensitivity checks to various parameters, the observed change in specific sound level has been defined as uncertainty. This uncertainty was tracked across 61 recent AQMAU audits of NIAs submitted in support of environmental permit applications from 2022 to 2023. This paper presents an analysis of the associated uncertainty and how often each area of uncertainty occurs.

## 2 METHODOLOGY

### 2.1 Aims

In order to derive a method for the review and quantification of modelling uncertainty, a set of aims for the study were set out as below.

- Identify and track the occurrence of each approach to propagation calculations within noise impact assessments, that introduced potential inaccuracy, audited by AQMAU in 2022 and 2023.
- Quantify the change to the predicted specific sound level following actions taken in AQMAU audits for each parameter considered. This change in specific sound level is defined as the level of uncertainty for that approach to propagation calculations

### 2.2 Noise audit review

The review considered 61 audits of NIAs submitted for environmental permit applications. Each individual element of uncertainty and the impact that each item had on the BS 4142 assessment outcomes was logged. The results are shown in Section 4 and there is discussion of these results in Section 5 of this paper.

The method employed for this study is not an attempt to quantify absolute uncertainty associated with each propagation calculation method. This is because, there is no objective magnitude associated with a propagation calculation approach when considered within a site-specific scenario. For example, in one case a missing sound source, once included in a propagation calculation, could increase the specific sound level by 10dB. In another scenario the inclusion of the missing sound source could make less than 1dB difference to the specific sound level, potentially due to obstacles on site, or possibly the missing source is not a dominant sound source at the receptor. Therefore the uncertainty of the calculation method is dependent upon the submitted calculation parameters and their deviation from accurate or real-life conditions on site.

Hence, this study aims to present the observed uncertainty of the various approaches to propagation calculations, drawing on AQMAU observations and sensitivity checks to various parameters as seen in actual site-specific scenarios. This method of quantifying uncertainty is perhaps more representative of the overall uncertainty associated within each individual NIA.

# 3 TOPICS OF UNCERTAINTY

The different approaches to propagation calculations which were tracked within this study are summarised in Table 1 below. A description of each topic is provided, along with grouping into categories for further analysis within this study. Additionally, the parameters upon which the uncertainty depend are also detailed in the table.

Table 1: Topics of quantified uncertainty which were included within uncertainty analysis.

| Topic | Description of uncertainty | Uncertainty magnitude is dependent on |
|---|---|---|
| **Sources -** Line source $L_W$ calculation for point source | The sound power level for a point source is derived from a measurement of sound pressure level assuming line source propagation, as opposed to more representative point source propagation. Typically applied to a measurement of a single item of mobile plant which would approximate to a moving point source as opposed to a line source. | The location, height and sound power level of sources. Typically leads to underprediction of specific sound level. |
| **Sources -** Open doors not included on buildings | Buildings are modelled with the sound reduction index for the facade construction extended over doors which are intended to be either fully open or be open for part of the time during typical operations. This overestimates the sound reduction index for these elements of the building. | The location, height and sound power level of open door relative to receptors. Typically leads to underprediction of specific sound level. |
| **Sources -** Reverberant $L_p$ incorrectly calculated | Unrealistic internal absorption coefficient values, or unrepresentative value of Cd[3] used relative to diffusivity of the internal room, or reverberant sound pressure level is not correctly derived from the sound sources to be located within a building. | The assumed internal absorption area, source sound power levels and building dimensions. Leads to either underprediction or overprediction of specific sound level. |
| **Sources -** Unrepresentative source on time | On time (operational time) correction not representative of the site operations, or modelled correction does not match what is detailed within the noise impact assessment. | The ontime correction applied. Leads to either underprediction or overprediction of specific sound level. |
| **Sources -** Low $L_W$ for sound sources | Source sound power level is lower than expected when compared to sources reviewed on similar sites for similar operations or when compared to reference data (for example from BS 5228[4]). | The location, height and difference between representative sound power level of sources. Typically leads to underprediction of specific sound level. |
| **Sources -** Sources inaccurately located | Sources may be placed in a more screened location (adjacent to buildings/barriers) or placed further away from receptors when other information, such as site drawings, shows they will be placed in a more exposed location. | The location, height and sound power level of sources. Leads to either underprediction or overprediction of specific sound level. |
| **Sources -** Missing sources | Sources missing from model that were mentioned in the noise impact assessment, or operational activities mentioned elsewhere in the environmental permit application that were not included within the noise impact assessment. | The location, height and sound power level of sources missed. Typically leads to underprediction of specific sound level. |
| **Sources -** Directivity of source not representative | Directivity may either not be applied accurately to a source or may be ignored when deriving a sound power level for a source when off-axis sound pressure level measurement has been used that is unrepresentative of the direction of sound propagation to receptors. | The relative locations of the source and receivers. Leads to either underprediction or overprediction of specific sound level. |
| **Sources -** Source height not representative | Sources assigned lower than representative or with no height in model, not indicative of the accurate acoustic centre of source. | The location, height and sound power level of source. Typically leads to underprediction of specific sound level. |
| **Sources -** Broadband source data | Diffraction and transmission may not be accurately calculated along the propagation path, especially where a number of screening obstacles have been included. Also | Diffraction/transmission around/through obstacles and building walls, frequency characteristics of particular source, |

| Topic | Description of uncertainty | Uncertainty magnitude is dependent on |
|---|---|---|
| | heightened uncertainty when predicting sound breakout through structures for internal sources as sound reduction index cannot be applied accurately across the frequency spectrum. | particularly when low frequency is dominant. Leads to either underprediction or overprediction of specific sound level. |
| **Obstacles -** Unrealistic mitigation measures | Proposed mitigation measures that are unfeasible (e.g. barrier with large height) or not agreed with the operator have been included in modelling or calculations to reduce predicted specific sound levels. | How realistic the mitigation measures are with respect to likely cost and physical construction. Typically leads to underprediction of specific sound level. |
| **Obstacles -** Offsite barriers included in modelling | Barriers are modelled for timber fencing outside of the site under assessment. There is no guarantee of whether this will be maintained or if it meets the ISO 9613-2 definition for a screening obstacle (no large gaps or cracks and surface density of at least 10 kg/m$^2$). | Height and location of barriers relative to sources and receivers. Typically leads to underprediction of specific sound level. |
| **Obstacles -** Buildings made from barriers | This does not accurately represent sound breakout, within modelling software following the ISO 9613-2 method, diffuse conditions within the building and transmission through building elements is not accurately calculated. | Sound reduction index of building elements and source sound power level. Leads to either underprediction or overprediction of specific sound level. |
| **Obstacles -** Sound reduction index not representative | Typically, higher sound reduction indexes than would be representative for basic building constructions. Gaps and composite constructions (e.g. rooflights in steel sheeting) not considered. | The construction of the sound emitting building. Leads to either underprediction or overprediction of specific sound level. |
| **Obstacles -** Stockpiles included in LiDAR | The LiDAR data imported into model includes stockpiles from a singular point in time. These are liable to move or vary in height and are not reliable to provide the screening modelled. | The location, height and sound power level of sources. The location of receptors, the size and location of the stockpiles. Typically leads to underprediction of specific sound level. |
| **Obstacles -** Unrepresentative or no terrain heights | Where the ground heights across the source to receiver propagation path are not flat, including accurate terrain can lead to more exposed receivers if the site or receptor location is on a higher relative elevation. Alternatively, the terrain can provide further screening with intervening hills. | Source/receiver location and terrain heights relative to propagation pathways. Leads to either underprediction or overprediction of specific sound level. |
| **Obstacles -** High building absorption coefficient | Reflecting obstacles are modelled as more absorbing than they are likely to be relative to masonry/glass surface of most UK buildings. | How high the assigned absorption coefficient is. Typically leads to underprediction of specific sound level. |
| **Receptors -** Missing receptors | Receptors which have not been included within the assessment and are exposed to higher specific sound levels than other receptors. | Whether the missed receptors are the worst affected by site sound. Typically leads to underprediction of specific sound level. |
| **Receptors -** Receivers not in the worst case location | Typically, receiver(s) will be placed behind a building, or on the other side of the noise sensitive receptor building, where other aspects of the building façade or other facades are more exposed to site specific sound. | Screening within the model relative to receiver position and source locations. Typically leads to underprediction of specific sound level. |
| **Receptors -** Ground floor receptors only | Ground floor receptors typically most screened by buildings, barriers, terrain etc. Sometimes upper floor receptors are only included during the night time despite BS 4142 not indicating this approach. | Source/receiver (residential window) height and propagation path. proportional to the level of screening in the propagation path. Typically leads to underprediction of specific sound level. |
| **Receptors -** Receiver not representative of facade | Either the location of the receptor is unrepresentative of facade under assessment and/or includes facade reflection. | Receiver distance from facade under assessment. Typically leads to overprediction of specific sound level. |
| **Calculation -** No or low order of reflections | No reflections included. Alternatively, reflections have been included but are limited typically to 1 order of reflection, which may underpredict specific levels depending on the reflecting obstacles between sources and receptors. | The number of reflecting obstacles and the terrain relief between sources and receptor locations. Typically leads to underprediction of specific sound level. |
| **Calculation -**Ground absorption not representative | Typically occurs when ground absorption is included as a global value within the model, surrounding land use may be soft/mixed ground while site under assessment has hard ground. Therefore, source emissions from the site can be underpredicted. Alternatively hard ground can be assumed globally, leading to an overprediction where soft ground lies along the propagation path. | Ground absorption value assigned, site and surrounding land ground type. Leads to either underprediction or overprediction of specific sound level. |

# 4 RESULTS

This section details the results of the review of 61 AQMAU audits of NIAs submitted in support of environmental permit applications from 2022 to 2023. The two main aspects tracked within our review of propagation calculation were: how often did each topic of uncertainty occur; and what was the magnitude of the increase in specific sound level once these aspects of the propagation calculations were modified by AQMAU to closer reflect the onsite conditions.

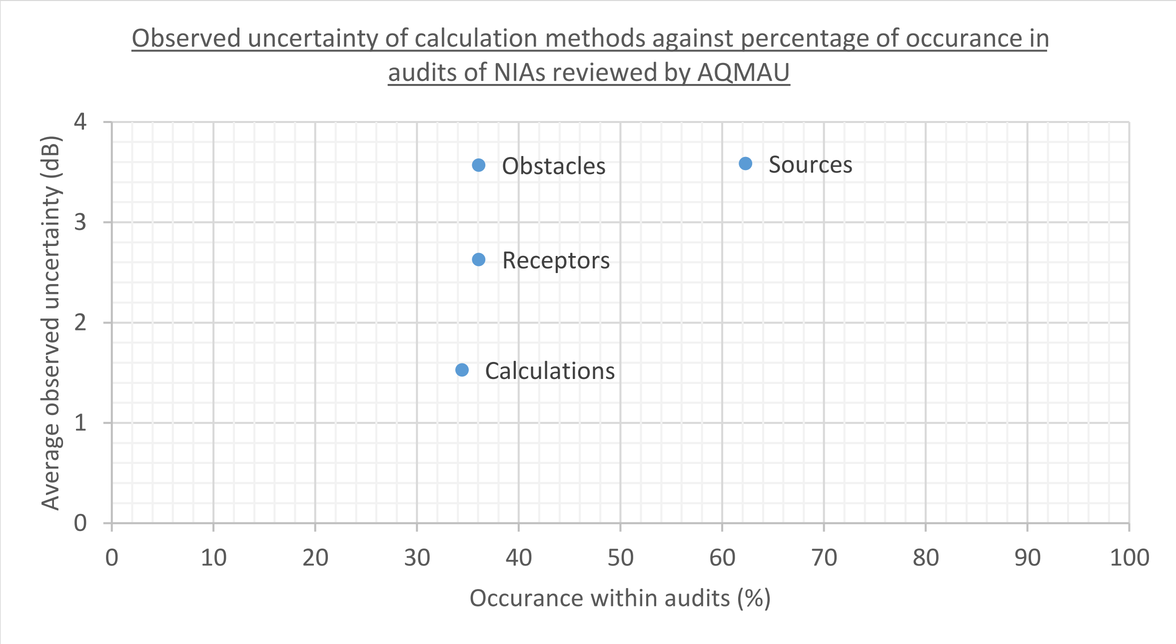


Figure 1: shows the magnitude of uncertainty associated with each topic group, and how often each was observed in audits of noise impact assessments. Details of the groups can be found in Table 1.

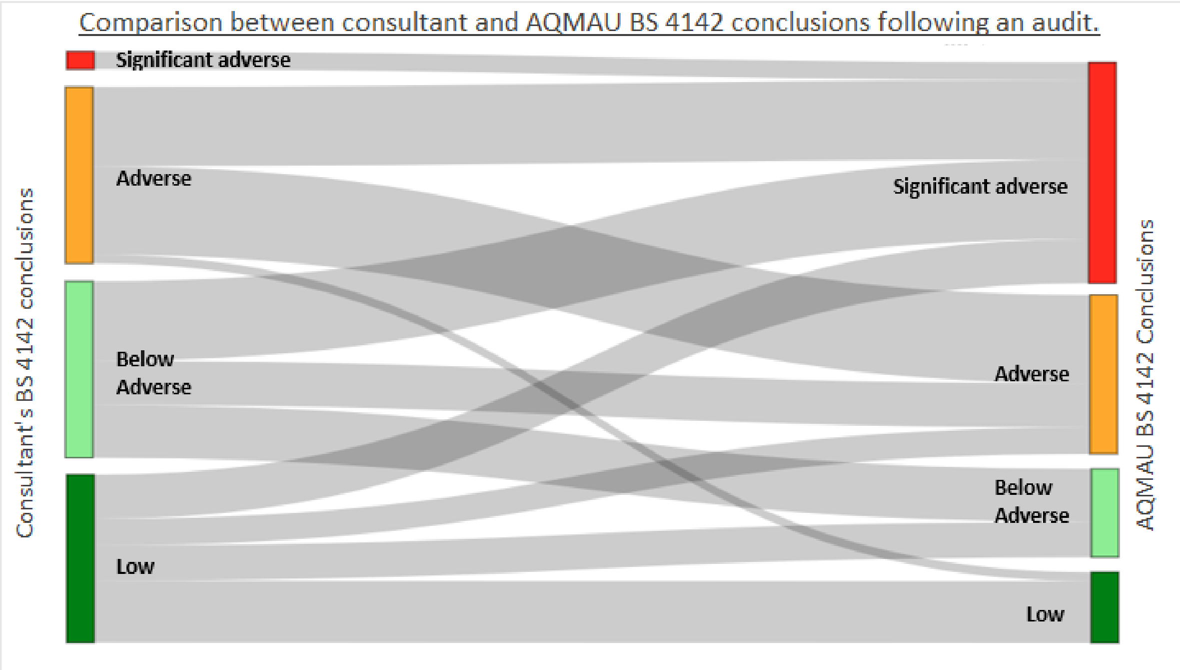


Figure 2: shows the BS 4142 conclusions of noise impact assessments submitted by applicants (left), compared with AQMAU BS 4142 conclusions following an audit (right).

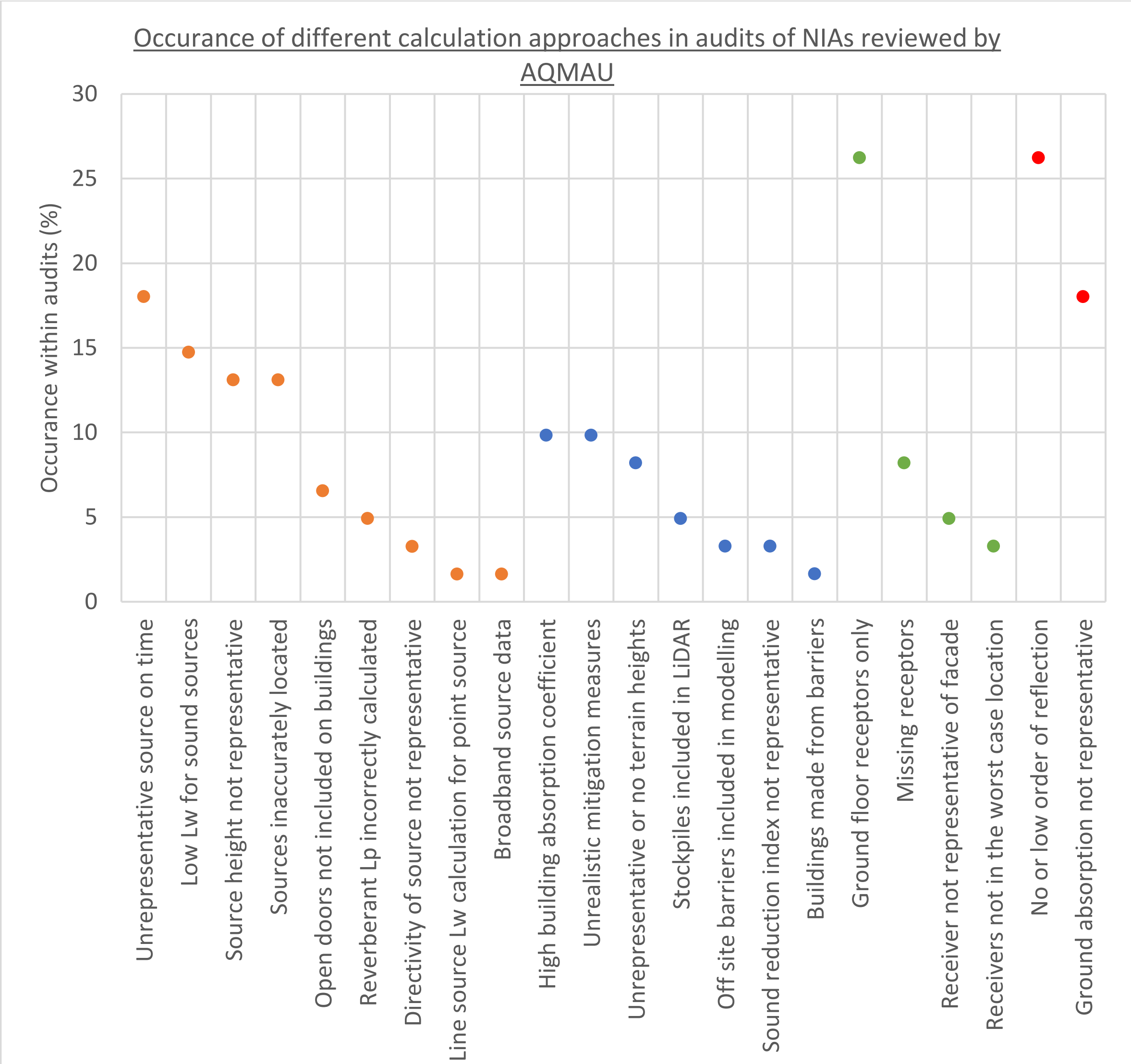

Figure 3: shows how often each element of uncertainty, as a percentage, occurred within applications reviewed by AQMAU, the items have been grouped as denoted by different colours, orange = sources, blue = obstacles, green = receptors, red = calculations.

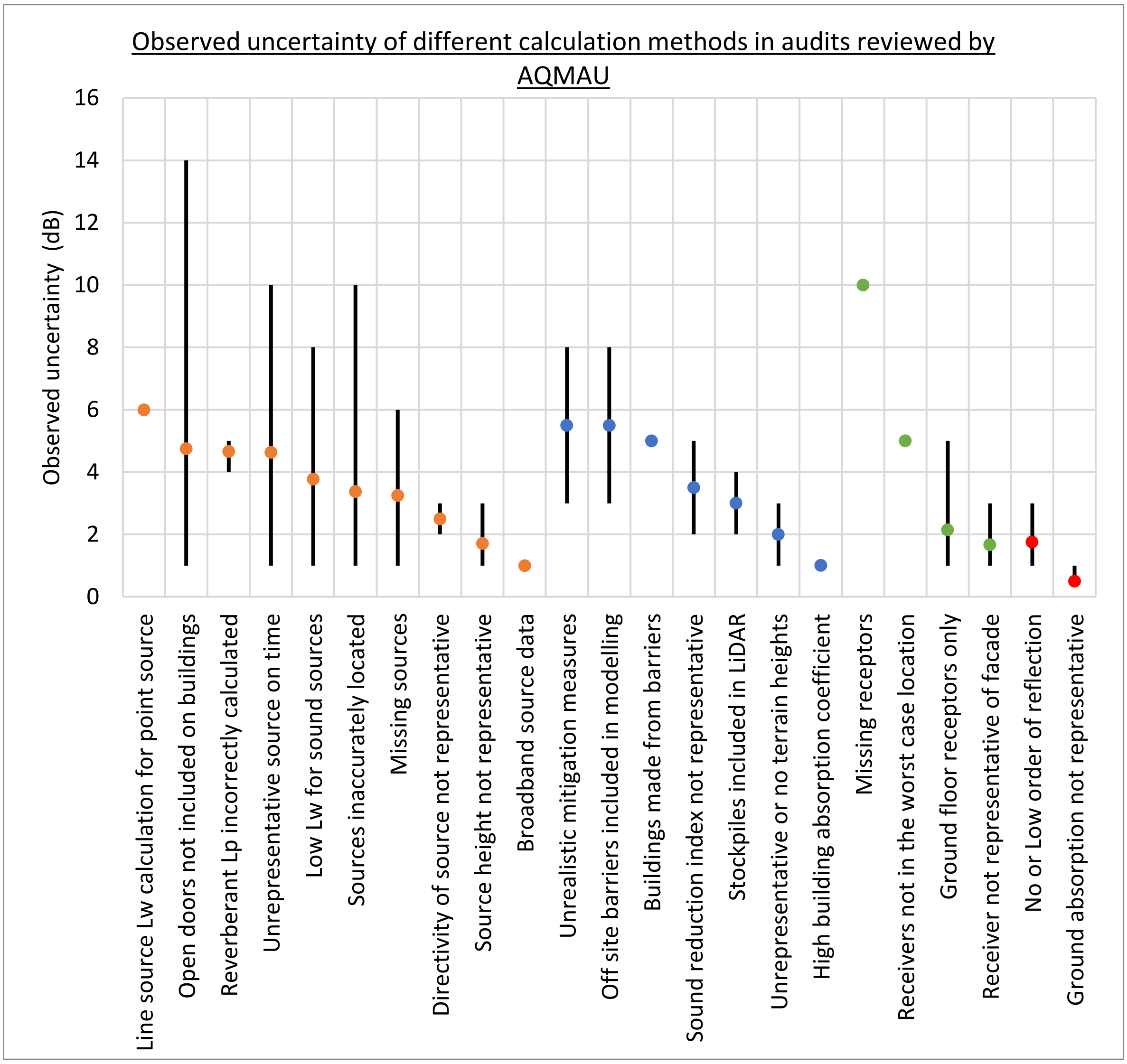

Figure 4: shows the average change in specific sound level following modifications made by AQMAU in audits, the items have been grouped as denoted by different colours, orange = sources, blue = obstacles, green = receptors, red = calculations. The black bars show the variation observed.

# 5 DISCUSSION

The following sections discuss the results as presented in Figures 1-4 and include further discussion regarding how these uncertainties impact the overall conclusion of a BS 4142 report.

## 5.1 Magnitude of observed uncertainty for propagation calculation methods

Within the propagation calculations reviewed by AQMAU, the largest magnitude of uncertainty was observed in the modelling of sound sources and obstacles. As seen in Figure 1, these two aspects of propagation calculations averaged a 3.6dB increase in the specific sound level following alterations made by the AQMAU to closer reflect the onsite conditions.

The largest magnitude of uncertainty observed within propagation calculations regarding sound sources was due to “line source $L_w$ (sound power level) calculation for point source”, (see Table 1 for details on this approach to propagation calculations). However, this aspect was only observed once within this review (see Figure 3), therefore it is not a reliable statement of the uncertainty associated with this aspect of propagation modelling. Of those topics which were observed more than once during the review, “open doors not included on buildings” had the largest associated average uncertainty (see Figure 4). An average increase of 4.8dB in the specific sound level was seen once this aspect was adjusted by AQMAU. Open doors also had the largest observed range of uncertainty, in one instance causing a 14dB increase in the specific sound level after accurately modelling the onsite scenario. The aspects with the second and third highest average uncertainty where “reverberant $L_p$ (sound pressure level) incorrectly calculated” and “unrepresentative source on time”. These aspects of uncertainty saw an average increase of 4.7dB and 4.6dB to the predicted specific sound level respectively when changed to more representative values.

For the modelling of obstacles, the largest magnitude of uncertainty was observed for the inclusion of “unrealistic mitigation measures”, such as impractically tall barriers. An average increase of 5.5dB in specific sound levels at receptors was observed once this approach was modified by AQMAU to closer reflect the onsite conditions.

### 5.2 Occurrence of propagation calculation methods

Within propagation calculations reviewed by AQMAU, the modelling of sound sources was the most commonly observed subject of uncertainty (see Figure 3). Roughly 60% of the audits reviewed by AQMAU contained aspects of propagation modelling related to sound sources which AQMAU modified to closer reflect the onsite conditions.

“Missing sound sources” was the most frequently seen individual aspect of uncertainty associated with propagation modelling of sound sources, occurring in 23% of audits. This was followed by “unrepresentative source on time” and “low $L_w$ for sound sources” which were seen in 18% and 14% of applications respectively (see Figure 3).

The modelling of obstacles was the second most commonly observed subject of uncertainty within propagation calculations reviewed by AQMAU (see Figure 3). Roughly 35% of applications reviewed by AQMAU contained an aspect of modelling of obstacles which AQMAU altered during our sensitivity check modelling to closer reflect the onsite conditions. “Unrealistic mitigation measures” was the most often observed individual aspect of uncertainty regarding obstacles, occurring in 9% of applications received.

Including “ground floor receptors only” (in residential buildings with at least two storeys), was the aspect of uncertainty within propagation modelling which occurred most frequently of any individual aspect of uncertainty (22% of applications). Environment Agency guidance[5,6] is clear that “the term ‘outside a building’ [assessment location within BS 4142] does not just apply to external gardens or land, it applies to balconies and outside any room where occupants would expect or need quiet – studies, bedrooms, sitting rooms. If there is no clear evidence that a room is unoccupied, you must presume that it is, for example an attic window”. In addition to this including “no or low numbers of reflections” within modelling also occurred in 26% of applications.

### 5.3 BS 4124 outcomes related to propagation calculations

With regards to a BS 4142 assessment, there is a range of only 5dB between adjacent impact bands (e.g. between adverse and significant adverse impacts). There are several aspects of modelling uncertainty detailed in this review which could lead to a 5dB increase in specific sound levels, and therefore change BS 4142 conclusions (see Figure 4).

A review of the BS 4142 conclusions shows that AQMAU found higher BS 4142 impacts compared to the consultant in nearly two thirds of cases (see Figure 2). In a further third of audits AQMAU agreed with the overall BS 4142 conclusions put forward by the consultant. Figure 2 shows AQMAU finds a substantially higher number of significant adverse and adverse impact conclusions following audits. It should be noted that analysis of background sound level measurements and context also

feature heavily in AQMAU audits[7]. Therefore, those instances where the AQMAU found higher impacts would not necessarily be due to uncertainty within propagation calculations alone.
To avoid delays in permit determination, special attention should be paid towards the aspects of propagation calculations which will have the largest effect on specific sound levels, and therefore conclusions of BS 4142 assessments. Figure 1 shows that the modelling of sound sources and obstacles within propagation calculations occurred most often and, when modified by AQMAU, saw the highest average increase in specific sound level. Therefore, it is likely that substantial savings of time, money and resource could be made by both applicants and regulators, if the uncertainty associated with these topics were minimised within future propagation calculations.

# 6 CONCLUSIONS

AQMAU has reviewed 61 completed audits of NIAs submitted for environmental permit applications during 2022 and 2023. The review aimed to understand the different approaches to propagation modelling taken by consultants and analyse the associated uncertainty of calculated specific sound levels. The modelling of sound sources and obstacles within propagation calculations occurred most often and, when addressed by AQMAU, saw the highest average increase in specific sound level. Propagation calculations related to obstacles and sound sources saw an average increase of 3.6dB in the specific sound level following alterations made by the AQMAU. In addition to this roughly 60% of the audits reviewed by AQMAU contained aspects of propagation modelling related to sound sources which AQMAU modified during our sensitivity checks.

AQMAU has seen that, of those submissions reviewed, roughly two thirds saw an increase in BS4142 impacts following an AQMAU audit. These findings are not only due to uncertainty within propagation modelling as analysis of background sound levels and context, amongst other aspects of BS 4142, play a vital role in AQMAU audits. However, the review does show that there are several aspects of propagation calculations which result in an average increase in specific sound levels exceeding 5dB, following AQMAU sensitivity modelling checks. Therefore, the accuracy of propagation calculations is an important factor where AQMAU finds higher impacts than presented in an applicant's noise impact assessment.

Where AQMAU finds significant adverse or adverse impacts, this typically triggers requests for information and potentially further mitigation measures. This review shows that improving the accuracy in propagation modelling overall and, in particular modelling of obstacles and sound sources, could save the regulator, applicant, and consultant's time, money and resources.

# 7 REFERENCES


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