A Balanced Approach to Managing Risk in Environmental Noise Assessments

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This paper discusses the findings of recent UK government funded studies into uncertainty associated with environmental noise variability, and its relevance to all aspects of environmental noise management including both measurement and prediction.

Spatial and temporal variability in environmental noise fields can introduce significant uncertainty about using data measured or predicted under one set of conditions to represent the environmental noise field outside that range of conditions. Methodologies selected for acquiring or predicting truly representative data are therefore vitally important. However, the selection of measurement or prediction methodologies is often influenced, not only by acoustic factors such as propagation effects due to meteorological conditions, but also by non-acoustic factors such as different interpretations of requirements, restrictions introduced by competitive tendering, limited timescales, and the availability of suitable quality input data. Such factors frequently prevent the selection of 'ideal' measurement and prediction strategies and emphasise the need for noise management policies that clearly define the relevant assessment conditions.

Together, the foregoing issues preclude the adoption of a 'standard' environmental measurement or prediction strategy applicable to all scenarios. Current government funded research aims to develop flexible but structured guidance on the selection prediction methodologies appropriate to different situations of varying acoustic complexity and for applications ranging from strategic to site specific investigations. The work ultimately recognises the need to achieve a balance between the capital and time cost of the selected methodology and the risk of an incorrect assessment outcome.

1 Background

Environmental noise fields are increasingly coming under scrutiny, with a rising emphasis on their objective rating, as encouraged by both National and European policy drivers. The ultimate aim is to enable more informed and consistent decision making relating to both local noise issues and, in particular, larger scale strategic noise management. Within this local to area-wide range of applications, the use of information concerning environmental noise fields is many fold, including applications such as:

- Research;
- feasibility studies for new developments;
- evaluation of existing noise sources;
- developing effective noise management strategies.

Environmental noise fields are objectively rated by way of either measurements, predictions, or a combination of the two. The rating may be directly in the form of a noise measurement index, such as the $L_{Aeq,T}$ or the L_{den}, or it may be in the form of, for example, the numbers of people exposed to noise levels within a given band of levels. The actual form of final presentation of results will be guided by the target audience. However, notwithstanding potential differences in the presentation of results, at some stage in any assessment it is required to assign a quantitative noise level to a given location or area. Technical developments in predictive modelling techniques have reduced the dependency on measurement as an objective rating tool. The emergence of practical predictive noise mapping tools complements, and in some cases provide a viable substitute for, more 'traditional' environmental noise measurements. Conversely, noise measurement techniques have also developed significantly, with central PC based systems using remote noise loggers becoming increasingly sophisticated in their ability to acquire and manage large quantities of noise measurement data. However, despite these ongoing technical developments in both fields, any attempt to objectively rate a noise field will inevitably be encumbered by an unavoidable margin of uncertainty. Depending on the particulars of the assessment under consideration, and the manner in which objective ratings are used to inform a decision making process, this uncertainty creates the risk of an incorrect assessment outcome. Given the scale of social/financial costs that may be associated with noise assessment outcomes, it is very important that these uncertainties are fully understood. Only if these uncertainties are understood can the potential risk of an incorrect assessment outcome be assessed and the risk subsequently managed to the ‘appropriate’ degree. It is the definition of ‘appropriate’ that is the important factor here, and it is this factor which the UK studies summarised in this paper have sought to define.

2 Can Noise Data Help?

The fundamental starting point for any noise assessment exercise should be the recognition that the measured or predicted noise levels will be used to inform some process. It must also be recognised that the process required to be informed will have associated with it some outcome and that the financial and social significance of this outcome will vary from situation to situation. For example, the installation of a small, domestic machine may result in elevated noise levels to neighbours. This could occur either because no account was taken of noise at all, or possibly because the potential noise from the machine has been assessed incorrectly: either the noise level of the machine has been underestimated and/or the masking level of the existing background noise environment has been overestimated. The resultant noise of the machine may be unacceptable to a few immediate neighbours and may need to be mitigated, but the resolution of the problem is neither likely to incur excessive costs nor to inconvenience too many people. In contrast, imagine the same lack of attention being adopted towards the development of, say, a large industrial facility adjacent to a densely populated residential area. The number of noise affected people is likely to be considerably greater. Likewise the costs and practicality of mitigating the problem could be extensive, with serious knock-on consequences to both the operation of the industrial installation and the large numbers of local population adversely affected by the noise.

The two foregoing examples may appear somewhat simplistic, but they nevertheless illustrate well the initial considerations to which due regard should be had in all situations where it is recognised that noise issues may influence the outcome of a decision making process. This is regardless of the type of decision the noise information is used to inform, be this research outcomes, local planning decisions or strategic area wide planning. Therefore, the basic questions required to be addressed at the initial stage of considering the use of any noise assessment exercise should comprise:

- first, will an increased knowledge of the noise issues, concerning either the existing noise environment or new noise source(s) proposed in an area, assist in arriving at a decision (the answer to this question will almost certainly be ‘yes’, but the relative importance of noise when considered in the light of all other factors affecting the decision outcome can not be overlooked when deciding whether or not a ‘yes’ means that a noise assessment is automatically justified);
- second, what would the consequences of an incorrect decision be, should noise either not be considered to the appropriate degree or not considered at all (the answer to this question will depend on the potential social and financial costs of an incorrect assessment outcome and how much noise may contribute to the risk of an incorrect decision, plus the costs of mitigating any resultant noise problems should they arise);
- third, if it is decided that information concerning noise will usefully inform the decision making process in the context of the consequences of an incorrect assessment outcome, then what level of ‘accuracy’ will be required of the noise data.

3 Variability and Uncertainty

It is the final bullet point of the preceding section that leads to the main thrust of the work reported in this paper: namely, what is meant by the ‘accuracy’ of environmental noise data, be this measured or predicted. In addressing this issue, the work has recognised the use of three frequently used terms when describing the validity of environmental noise fields: accuracy, variability and uncertainty.

What can be said with certainty, at least to within the accepted limitations of measurement/prediction tools being used and the competency of the operator, is that the measured or calculated noise level at a given location and a given moment in time is valid for the selected input conditions of the prediction / measurement. In the case of measured data it is the noise level that actually existed for the precise set of conditions that prevailed at the time of the measurement. In the case of predicted levels, it is the level of noise relating to the adopted noise propagation calculation methodology and the specific data set used as input to the calculation. However, environmental noise fields are inherently variable, both in space and time. The moment that a measured or predicted ‘true’ noise level obtained under one specific set of conditions is used to infer the noise environment at any other location and/or time, uncertainty is introduced in the assessment. Therefore, in the context of environmental noise assessments, which almost always rely on a sub-set of incomplete information concerning noise fields, any measurement or prediction of noise will have associated with it some degree of uncertainty in the context of its use for informing decision making processes. This is except in the highly unlikely event that the available data relates *precisely* to the temporal and spatial requirements of the assessment.

Therefore uncertainty naturally arises from the inherent variability of environmental noise fields. However, the fact that a given noise field may exhibit a high degree of variability does not necessarily result in increased uncertainty nor an increased risk of an incorrect assessment outcome. In fact quite the reverse is often true. Variability can be used to reduce uncertainty, but this can only be the case if the major sources of the variability are known and their effects understood.

As an illustration of the above, it is well known that upwind noise propagation can result in received noise levels that may be 15dB(A) or more lower for the same source than those experienced under light downwind propagation conditions. It is also known that received noise levels under upwind propagation can suffer significantly greater variability than experienced under light downwind conditions. For this reason many noise measurement standards require that measurements be undertaken in conditions of light wind blowing from the main source of interest towards the receiver. The output of many noise calculation methodologies are similarly based on the same premise of light downwind propagation. The fact that the effects of wind increase the variability of received noise level, probably to a greater degree than any other single parameter, is therefore used to advantage to reduce uncertainty associated with the measured or calculated noise level. However, this is only possible because the nature of the variability and the effects of wind on noise propagation are well established and can be appropriately accounted for.

Variability in both the measurement and prediction of environmental noise fields derives from a wide range of different sources. Dividing the problem into its three constituent parts, namely source, propagation and receiver, effects in any one of these elements can introduce variability in the received noise level. For example, in the case of road traffic noise, the flow of traffic on a road or whether the road is dry or wet can affect source levels. Likewise the meteorological conditions between the road and the receiver can also affect the propagation of the noise to the receiver. Local effects at the receiver, such as the open state of windows, doors etc., can also significantly affect received noise levels indoors. An additional consideration at the receiver is that the overall noise level may be the sum total of multiple sources of noise, such as roads both far and near, that may exist in many different directions relative to the receiver.

4 Measurement or Prediction?

To assist in decision making, any noise assessment exercise will usually have as its ultimate outcome goal a ‘derived’ value, or values, that would best represent the environment in question. The challenges of producing such a value (by way of prediction or measurement) must then relate to the wide range of values that may be exhibited by the naturally variable noise field. It is this variability in environmental noise fields, rather than ‘accuracy’ limitations of measurement and prediction tools that commonly presents the greatest source of uncertainty in environmental noise assessments.

The challenges introduced by the variable nature of environmental noise can be significantly compounded still further by practical constraints. Examples include finite budgets limiting the scope of noise surveys, or the limited availability of relevant input data to noise modelling exercises. Such resource limitations may restrict the scope of an investigation without sufficient regard being paid to the potential significance of risks that may be associated with an incorrect assessment outcome as result of these constraints.

Measurement and prediction methods each offer benefits and limitations that directly affect the decision as to which method will be most suitable for a given application – suitability judged here on the basis of achieving the most appropriate balance of assessment resource requirements, expected uncertainties, and potential risk significance. However, the relationship between measurements and predictions is frequently defined as one of ‘accuracy’, whereby misleading quotes are often made in relation to the ‘accuracy’ of a predicted noise level against a ‘true’ representation provided by a measured value. These types of relationships may have relevance in very well defined situations, but often neglect the inherent variability exhibited by real noise fields, and the fundamental flaw this introduces into any quoted ‘accuracy’.

The following three Figures illustrate the problems of defining accuracy in the context of environmental noise, and particularly in the context of the validation noise prediction exercises. These results were obtained as part of an extensive noise measurement exercise undertaken across 50 urban/sub-urban sites along a corridor within 2km of a major motorway. Measurements were obtained at each location for a minimum of two weeks. The figures show data for the same eight working days across the three separate locations. Wet days have been excluded from the graphed data to remove the effects of source variability other than changes associated with traffic flows.

Each figure shows as the thin solid lines with crosses as markers the measured hourly $L_{A10,1hr}$ noise levels. The two short dashed lines on each figure show the lowest and highest daily $L_{A10,18hr}$ for each data set. The heavy dashed line indicates the average $L_{A10,18hr}$, and the heavy red line shows the calculated $L_{A10,18hr}$ noise level calculated using the UK CRTN procedure. Calculations were undertaken using available traffic flow counts as used for a large scale noise mapping exercise of the area.

Figure 1: Noise levels measured ~20m from major road

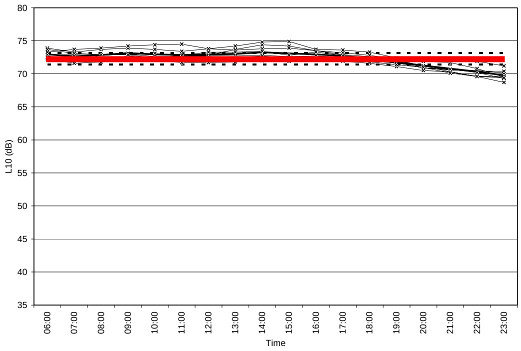


Figure 2: Noise levels measured ~300m from major road with motorway traffic noise dominant

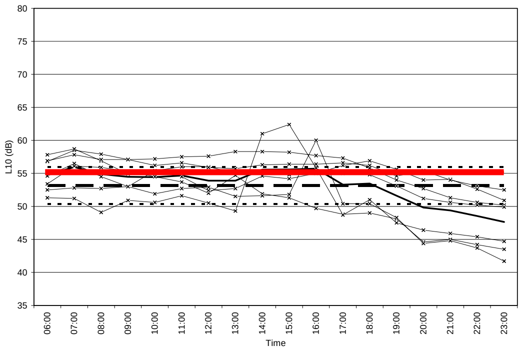


Figure 3: Noise levels measured ~300m from major road with non-road traffic source dominant

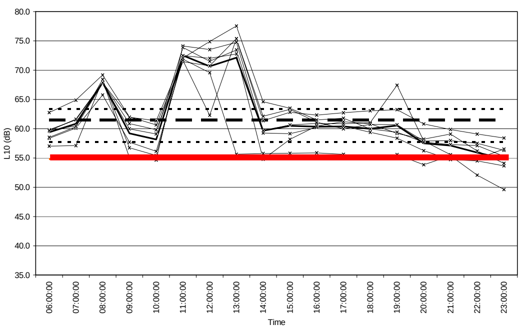


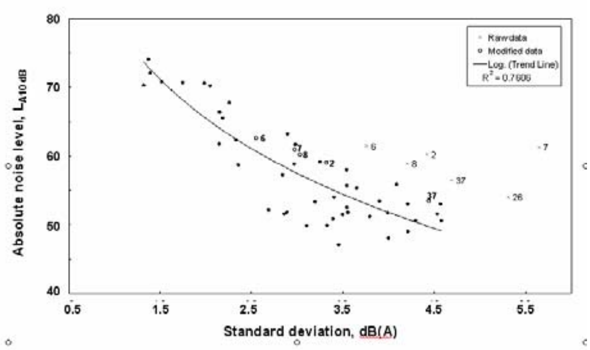
Figure 1 shows the hourly noise levels measured over 8 working days at a location approximately 20m from the major road. As expected the overall noise levels are high at over 70dB(A) and show little variability from day to day, with less than 2dB(A) separating the lowest and highest $L_{A10,18hr}$ levels. The predicted level lies within this 2dB(A) range, within 1dB(A) of the average $L_{A10,18hr}$ noise level.

Figure 2 shows the noise levels measured approximately 300m from the major road. As expected the absolute noise levels are significantly lower at around 55dB(A) at this location and day to day variability is increased, with a range of 7dB(A) between the minimum and maximum daily $L_{A10,18hr}$ noise levels. The predicted noise level lies within this 7dB(A) range but approximately 3dB(A) above the average $L_{A10,18hr}$ noise level. Due to the lower overall noise level a few of the $L_{A10,1hr}$ data points are corrupted by extraneous sources of noise, but these are not significant in the overall analysis.

Figure 3 shows the noise levels measured at a similar distance from the major road as for Figure 2, but this time the results are significantly affected by a non-road traffic related source of noise, a nearby playground. In this case the predicted level lies some 7dB(A) below the average measured $L_{A10,18hr}$ level. This situation is not at all surprising given that the predictions are based on road traffic sources and do not account for extraneous sources such as playground noise, but it does illustrate the fact that variability in measured noise levels may be significantly increased in practice due to local effects.

One general finding to have come out of the analysis of the full 50 site data set referred to above is evidence of a strong inverse relationship between the absolute level of noise and the temporal variability associated with that noise level. The following Figure 4 shows the average noise levels measured across the 50 measurement locations plotted as a function of the standard deviation of the measured levels at each site. Standard deviations range from less than 1.5dB(A) at noise levels of around 70dB(A) to 75dB(A), increasing to around 4.5dB(A) at noise levels of around 50dB(A).

Figure 4: Inverse relationship between the absolute level of road traffic noise and the standard deviation of the measured noise levels



It must be stressed that this conclusion can only be applied to similar urban/sub-urban sites within the range of noise levels considered here, between around 50dB(A) and 75dB(A), and only to noise environments dominated by road traffic noise. It is, nonetheless, a useful finding as it provides typical ranges within which one can begin to rate the 'accuracy' of noise measurements and predictions, particularly when the outputs of the two different techniques are being compared.

It is noted that six of the data sets shown in Figure 4, all identified by the individually numbered crosses, were identified as being corrupted by non-road traffic sources, including the data shown in Figure 3 where playground noise was an issue. These six data sets all demonstrated a standard deviation that was significantly greater than that indicated by the trend line in Figure 4. It was only when the periods of time affected by the extraneous sources were identified and, where possible, these were removed from the data sets to leave just the effects of road traffic noise that the standard deviations fell into line with the general trend.

Given the difficulties of defining a set condition in which there is a unique and regularly occurring noise level, the immediate question must be that of 'accuracy' relative to which noise level? Further, such interpretations will often undermine the relative merits of prediction and measurement, potentially leading to incorrect biases over the reliability of measurement data as a decision making tool. Instead, efforts would be better directed fully understanding the relative merits of each in order to enable better choices to be made when instigating any investigation to objectively rate a noise field.

5 The Guidelines

The above concepts have provided the basis for the development of new UK guidance developed under the National Measurement System (NMS) Directorate that is responsible for providing traceable and enhanced standards of measurement for use in trade, industry, academia and government. Guidance has been separately developed to deal with issues surrounding the selection and design of measurement strategies targeted at managing uncertainty and potential risk. Further related guidance is currently proposed to be developed that addresses overlapping issues affecting prediction uncertainty. The central concept to the advice proposed by each is the need to consider assessment uncertainty prior to committing to any particular course of assessment method. The aim of this approach is to ensure that the relative merits of all possible assessment strategies are properly compared at the outset. Only by considering the issues at this early stage of any assessment can resources be both appropriately and efficiently allocated to address potential risk arising from assessment uncertainty. In so doing, it is anticipated that the guidance will:

- Promote awareness of the sources of uncertainty in environmental noise assessment, and the potential risk this uncertainty introduces.
- Promote an awareness amongst all users of environmental noise assessments that the selection of appropriate assessment strategies is a case-specific process that must recognise the complexities of the acoustic environment under consideration, the type of assessment criteria defining the requirement for objective ratings, the significance of any decisions to be based on the assessment (eg. the scale of social/financial costs) and the likelihood that the assessment will yield a rating in close proximity to a prevailing decision trigger point.
- Enable informed choice when proposing the use of either measurement and prediction or a combination of the two.
- Assist decisions surrounding the allocation of appropriate resources to the noise assessment exercise.
- Enable the use of any restricted/compromised assessment methods in full recognition of the associated risks and limitations.
- Enable the selection of the most appropriate strategy of measurement, prediction, or some combination of the two, that strikes the correct balance between the initial resource requirements of the assessment, the significance of the decision making process that the assessment seeks to inform, and the potential risk associated with any sources of uncertainty

6 Conclusions & Summary

This paper has considered the issues surrounding the 'accuracy' of environmental noise measurements and predictions based on the outcomes of a UK based study of uncertainty in environmental noise. The findings of this study will result in the production of formal guidelines. In summary, the guidelines will propose a generalised methodological approach to managing risk in environmental noise assessments, whilst recognising that every assessment is different and there is no 'one size fits all' solution.

The generalised approach will require the user to consider potential risk associated with measurement/prediction uncertainties at all stages of the assessment. The user must always keep in mind the fact that the outcome of the noise assessment will only be useful if it usefully informs some process. With this in mind, the 'accuracy' requirements of the final output of the decision making process must drive the ‘accuracy’ requirements of the noise assessment from the very outset. This general approach may, in some instances, lead to the conclusion that a noise assessment will not usefully add anything to the final decision making process where, traditionally, a detailed noise survey would have been undertaken as a matter of course. In other situations the approach may result in significantly greater effort being expended on more detailed noise assessments than may traditionally have been the case. At the very least, these considerations will ensure that the noise assessment is appropriately tailored to the information requirements, and also that risk introduced by uncertainty is managed appropriately at all stages of the process. The four basic stages may be summarised as follows:

1. determine whether a noise assessment can usefully inform the decision making process within the context of the overall outcome requirements of the process;
2. design the noise assessment strategy, determining whether the assessment can still usefully inform the process within the available resources and other constraints;
3. execute the noise assessment, taking full account of possibly hitherto unaccounted for factors that may affect the uncertainty associated with the assessment’s output;
4. analyse and report the results of the assessment, checking that original assumptions concerning risk introduced through uncertainty have been controlled to the appropriate degree.

The main issues driving the need for such guidance have been identified as:

- Environmental noise is inherently variable and can therefore be difficult to objectively quantify. Therefore, before attempting to use objective descriptions of noise environments as a method of decision making, each situation should be scrutinised to evaluate whether such a objective rating is the best method of informing the decision.
- Measurements and predictions are both encumbered by an unavoidable margin of uncertainty. Differences between measurement and prediction can not automatically be used to deduce ‘inaccuracy’ in any given method. Such differences vary according to a range of factors, and underline the limitations that confront the use of measured or predicted data to inform decisions.
- Once a decision to formulate objective noise ratings has been made, it is important that the relative merits and limitations of measurements and predictions are carefully balanced specific to the situation at hand, in order that the available resources are allocated to the most robust/appropriate assessment method.

Irrespective of the chosen method of assessment, the level of effort invested in the assessment should relate to several important influencing factors:

- the likely proximity of the derived value to a decision trigger value (e.g. if a preliminary assessment exercise suggests a 20dB(A) difference between the noise level of interest and some criterion value then further effort will most likely not be required, but if the margin is 2dB(A) with an expected uncertainty of plus or minus 3dB(A) then further investigation may well be warranted dependent on other factors concerning the importance of noise in informing the decision);
- the social and economic differences between a positive or negative assessment outcome;
- the financial implications of rectifying an incorrect assessment decision (e.g. could excess noise be readily and practicably attenuated at a cost not significantly in excess of that which would have been incurred prior to construction of a development, or similarly could noise data be retrospectively and cost effectively obtained for strategic exercises);
- the nature of the prevailing assessment framework, and the type of derived value to be produced (e.g. a pass or fail value may be sufficient in some cases based on relative levels, but equally some assessments may require an absolute value to be determined).

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