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Accuracy implications of computerized noise predictions for environmental noise mapping

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ABSTRACT

The trend over the last 30 years has been for environmental noise prediction models to become more complex and the demands of projects to increase. A current project may include predicting noise levels at several million locations on a 10m grid across a city such as London, Paris or Hong Kong, and this therefore requires a computerized implementation of the noise prediction methodology. The use of computerized implementations allows large area noise maps to be produced but introduces a whole new range of potential problems in producing accurate maps in realistic timescales. This paper reports on work carried out for the United Kingdom government on issues such as the interpretation of prediction standards in different noise mapping software and the impact of efficiency techniques used in the software to reduce the calculation time. The study looked at specific prediction methodologies in use in the United Kingdom but the issues are relevant to any large scale environmental noise prediction software.

1 INTRODUCTION

Over the last 25 years that I have been involved in carrying out large scale environmental noise predictions, the scope of the work that has been carried out has changed enormously. In the United Kingdom, transportation noise prediction methodologies were generally introduced for a specific reason, usually linked to a legislative requirement. The methodology for calculating road traffic noise (CRTN) [1] was originally published in 1973 to provide a system of assessing the eligibility for noise insulation for properties next to new or altered road schemes. Likewise, the methodology for calculating railway noise levels [2] was introduced in 1995 to assess eligibility for noise insulation for properties next to new or altered railways. The methodologies were developed as a series of charts with formulae that could be used for more accurate predictions. The methodologies were developed for a relatively narrow range of predicted noise levels as the outcome of the exercise was a Yes/No decision. It was possible to carry out assessments for a new road scheme using scale plans, a calculator and a protractor.

Gradually, the scope of noise assessments increased. It was desired to look at the overall noise impact of a new road scheme, not just to consider which of the properties close to the scheme warranted the provision of noise insulation. In the absence of any other relevant prediction methodology, CRTN was used to predict noise levels at much greater distances from the road. The increased numbers of properties and the more complex road layouts being considered spurred the development of various software programs to carry out the calculations. During the 1990's the concept of noise mapping whole cities developed in Europe. This introduced the idea of producing noise contour maps, often based on a grid of noise calculation

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points at 10m intervals. This level of calculation effort was no longer feasible by hand, and software was developed that was capable of using digital mapping data to carry out the millions of calculations required.

It is now commonly accepted that noise mapping software is used for calculating contour plans of noise from roads, railways, aircraft and industrial sources. The software provides a cost effective method of considering the impact of noise across large areas and providing results in a format that can be appreciated by the general public as well as specialists. On the surface, noise mapping is a big step forward in disseminating information to the public in a comprehensible format. However, in order to maintain the belief of the general public in noise maps, it is necessary to be aware of and address the accuracy issues inherent in noise maps. Failure to deal with this issue will lead to noise maps being published containing large errors, and the general public losing faith in the process.

2 SOURCES OF ERROR

There are a number of potential sources of error in the process of noise mapping, which can combine to produce large errors in predicted noise levels. Errors in calculation methodologies, errors in computer implementations of methodologies, errors in input data, errors introduced in processing data for noise mapping, errors introduced in the software calculation of noise levels – efficiency techniques.

The above issues are relevant for modeling specific noise sources. When comparing results from noise maps against measured ambient noise levels, other issues become relevant such as noise sources not covered by the prediction methodologies e.g. human noise, wind noise, water noise. These become particularly important when predicted noise levels are low, but this topic is outside of the scope of this paper. The aim of this paper is to provide some practical guidance on the issues to be aware of, the magnitude of errors that can be introduced and ways of managing error issues in the noise mapping process.

2.1 Errors and uncertainties in calculation methodologies

Noise mapping software is often currently used to implement calculation methodologies that were initially developed 20-30 years ago. The CRTN [1] was originally developed in the early 1970’s. It was amended in 1988 but the basic methodology developed in the 1970’s was retained. Calculation methodologies developed in the 1970’s, 80’s and 90’s were usually developed to be able to be implemented by hand calculation with the use of a calculator, and were not developed with software implementation in mind. CRTN did provide some worked examples in annexes at the back of the document, which have been useful in providing verification checks for software developers. However, the annexes do illustrate some inconsistencies of the calculation methodology as well as the limitations of the way in which they were developed.

CRTN uses a simple methodology to take account of reflections from buildings and barriers located on the opposite side of the road. Unfortunately, it does not specify how far back from the road that buildings and barriers are considered as reflecting objects. Conflicting advice is demonstrated in the annexes with the value of 20m being implied as the cut off distance in one annex and a façade 35m away being identified as reflecting in another annex. Another example in CRTN is that the annex examples often assume an infinitely long road providing an ‘angle of view’ of the road of 180^0 at a property close to the road. The methodology of applying the ‘angle of view’ correction can be suitably implemented by noise mapping software, but the difficulties of mapping an infinitely long road in a software package mean that it is difficult for a software package to demonstrate complete compliance with the hand calculated results in the annex.

2.2 Errors in computer implementation of prediction methodologies

Part of the work carried out recently for the Department of Environment, Food and Rural Affairs of the UK government (DEFRA) was to look at the implementation of the three prediction standards that will be used for the first round of END noise mapping in the UK – CRTN, CRN and ISO 9613[3]. There has been a number of papers published discussing some of the issues of implementing prediction methodologies in noise mapping software. The paper by Shilton and Stapelfeldt [4] provides references to a number of these papers. Unsurprisingly, some of the uncertainties in the prediction methodologies are dealt with differently by different software developers. The work carried out for DEFRA involved comparing the hand calculation results for the annex test cases in CRTN and CRN with the results obtained in five different noise mapping software. Table 1 below shows the range of variation obtained for the various software. Most of the results were within 1 dB(A) of the hand calculation result. However, the study did demonstrate some significant variations from the prediction methodologies by the various software. CRTN contains a complex method to adopt when a road segment is orientated directly at a calculation point. This basically involves offsetting two calculation points and taking the mean of the calculated levels for these two points. It was discovered that one software ignored this procedure completely by ignoring road sections which were orientated directly towards a calculation point.

Table 1: Range of the discrepancy between the different software results and the CRTN hand calculation results.

Software	Difference
A	-1.4 to +0.5 dB(A)
B	-0.8 to +1.0 dB(A)
C	-2.5 to + 1.3 dB(A)
D	-1.8 to +0.6 dB(A)
E	-3.0 to +0.8 dB(A)

In addition to the issue of whether the software are providing different results to those obtained by carrying out hand calculations, perhaps a more important issue is whether the different approaches to implementing the calculation methodologies in the noise mapping software are providing significantly different results when looking at a large area noise map. It is not realistic to compare the results of a noise map containing a large number of calculation points with hand calculations considering the same number of noise sources. However, it is undesirable to have the different noise mapping software producing different noise maps for the same input data and calculation methodology. An assessment was carried out of the results produced by the five software for a 1 km^2 calculation area within a 25 km^2 model. The calculations were run for a 10m grid of receptors, producing 10,000 results. Statistical analysis of the results was carried out to determine the differences in the results. Table 2 below tabulates the results by comparing the results of the other four software packages with Software A. The greatest mean difference between two software is nearly 2 dB(A), and the greatest individual difference at a calculation point is 11 dB(A). These differences are sufficient to indicate that the use of different software using the same input data can have a significant difference on the overall results of a noise map.

Table 2: Difference statistics for Software A compared with other Software for CRTN calculations.

	Software B	Software C	Software D	Software E
Max Difference dB(A)	0.54	3.22	11.07	2.05
Min Difference dB(A)	-5.83	-1.76	-1.37	-1.81
Mean Difference dB(A)	-1.65	0.47	0.83	-0.17
Standard Deviation dB(A)	1.29	0.87	2.03	0.83

2.3 Errors in input data

With noise mapping, as with other computer applications, the 'gigo' principal of garbage in, garbage out applies. Work was carried out by Hepworth Acoustics for the UK government on assessing the implications on acoustic accuracy of WG-AEN's Good Practice Guide [5]. This work identified that small errors of input data could have different levels of impact on accuracy depending on the type of input data. Therefore, a full understanding is required of the impact on overall accuracy of inaccuracy in individual datasets. This is particularly the case if there is a step change in the calculation methodology. The inter-relation of inaccuracy of individual datasets is also important. A 1 dB(A) error in all input datasets is likely to lead to more than a 1 dB(A) error in the final result.

In an ideal world, all required data would be available for a noise map, but when considering large area maps, it is extremely unlikely that all required data is available. Therefore, a strategy is required to deal with data gaps that will have a known impact on accuracy. Version 2 of the WG-AEN Good Practice Guide provides some information on strategies for dealing with data gaps and likely decibel errors.

2.4 Errors from data simplification

One of the major issues associated with producing noise maps for large areas is calculation time and cost. Noise maps can involve calculations at several million grid points, with each grid point considering many noise sources over an area of perhaps 25 km^2. Noise calculations can be spread over a number of machines, but increased costs associated with software licenses can constrain this option. There is therefore a trend for software users to reduce the amount of data used in the calculations in order to speed up calculations.

The geographical data that is supplied is often generated for other purposes and is not optimized for noise mapping. The data is often much more detailed than is necessary for noise mapping. For example, a straight line may be defined by 100 points or nodes along the line. This can cause noise mapping software to carry out additional calculations as it looks at each segment of the line between each adjacent pair of nodes. Removing the 98 intermediate nodes and defining the line by the two end nodes will cause no loss of accuracy and will speed up the calculation. However, a curved line defined by a number of nodes is a much different situation, over zealous removal of nodes can cause significant differences in screening, causing significant differences in noise levels.

GIS software allows users to carry out sophisticated techniques to reduce the size of data files. This can include 'smoothing' items such as ground contours so that the number of nodes is minimized but the revised ground contour still provides the essential information required for noise mapping. The contour line is ‘smoothed’ to a tolerance specified by the operator. A tolerance of 0.1m would mean that no part of the ‘smoothed’ contour is more than 0.1m away from the original contour. This operation can produce dramatic reductions in size of data files, however, if not adequately controlled it can have large impacts on noise calculations. A tolerance of 10m would be sufficient to move a contour from one side of the road to another, significantly affecting screening attenuation.

2.5 Errors from efficiency techniques

In addition to ensuring that the amount of data that is used in the calculations is minimized, software developers have also introduced a number of efficiency techniques in to noise mapping software in order to reduce calculation times. As part of the research work carried out for DEFRA, a study was carried out in to the efficiency settings contained within 5 noise mapping software and their impact on accuracy. This work is reported in more detail in two papers presented at Euronoise 2006 by Hepworth, Trow and Hii [6] [7].

The work concluded that there was a wide range of efficiency techniques used by software developers, with almost no commonality between software. There was often little or no information in the software manuals about the impact on accuracy of using the efficiency techniques. Some efficiency techniques could be very effective, with one example reducing calculation time by 99% for an error of 1 dB(A). However, some efficiency techniques did not actually reduce calculation times, and others introduced errors of up to 5 dB(A).

3 WAYS OF MANAGING ERROR ISSUES IN NOISE MAPS

It is considered that only by having a full understanding of the potential sources of error in noise maps can informed decisions be made to minimize errors. The following recommendations provide an initial checklist for issues to be considered.

3.1 Calculation methodologies

A full understanding of the calculation methodology should be obtained prior to carrying out noise mapping. Any inconsistencies within the calculation method should be investigated and the effect of the inconsistencies understood. It is recommended that an agreed interpretation of the calculation method should be documented. Ideally, this should be developed by the ‘owner’ or organization that maintains the calculation methodology. If this is not possible, the noise mapping client may need to document the interpretation of the calculation method. The agreed interpretation should then be communicated to the noise mapping software developers, so that they are all using the same interpretation of the calculation method.

In order to check that the software developers are implementing the agreed interpretation of the calculation method correctly, check calculations should be required by each noise mapping software. Relatively simple model scenarios, similar to those contained in the Annexes of CRTN and CRN can be developed to ensure that the software are correctly implementing specific aspects of the calculation method. ‘Hand calculation’ results can be provided with an acceptable error specified by the client. Successful verification of the software results against the hand calculated results will ensure that the software is correctly implementing the requirements of the calculation method.

3.2 Data errors

A full consideration of the likely errors in the input data should be carried out to assess the level of accuracy required for data to be used for noise maps. There is little point in spending large sums of money acquiring geometric data to an accuracy of 1 dB(A) if traffic data is only accurate to 5 dB(A). Consideration of the level of accuracy of all data will also help to assess the accuracy requirements of data simplification techniques. It is likely that some of the geometric data will be too detailed and simplification will be proposed by the mapping contractor. However, firstly an accuracy requirement should be specified to the contractor, and then data should be provided to demonstrate the effect of the proposed data simplification on a test area to demonstrate compliance with the specification. The data should demonstrate that the combined effect of all data simplification techniques still meet the accuracy specification.

3.3 Efficiency techniques

Any noise maps submitted by the contractor should clearly specify what settings have been used when carrying out the noise map calculations. This should include the settings used for efficiency techniques. Data should also be provided demonstrating the impact of the efficiency techniques on accuracy of the results for a test area.

4 CONCLUSIONS

A number of practical recommendations have been provided to allow clients and contractors to make informed decisions on accuracy issues in large area noise mapping. A fuller understanding of accuracy issues will enable public confidence in noise mapping to be maintained by ensuring that maps are produced of a known accuracy. This process will also help to maintain a level playing field for the assessment of noise mapping proposals by different contractors using different software.

5 REFERENCES

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