ACCURACY IMPLICATIONS OF USING THE WG-AEN GOOD PRACTICE GUIDE TOOLKITS

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SUMMARY

In support of the WG-AEN, DEFRA has recently commissioned a research project to further extend the range of available Toolkits within the forthcoming Version 2 of the Good Practice Guide. The study have developed six additional Toolkits, and carried out Monte Carlo simulations, alongside mapping based sensitivity tests, in order to propose quantified decibel accuracy indicators in place of the original symbols. This paper sets out an overview of the purpose and design of the proposed new GPG Toolkits, as well as presenting the quantified accuracy indicators and extended practical guidance for noise mapping practitioners. The paper will focus on the practical outcomes of the research project in order to inform competent authorities on how the work may be used to deliver cost effective, quality controlled, environmental noise maps to meet the requirements set by the European Noise Directive.

BACKGROUND

In its capacity of support for the chair of the European Working Group – Assessment of Exposure to Noise (WG-AEN), the UK Governments' Department for Environment, Food, and Rural affairs (DEFRA) has let a research project to determine the likely effects, on the acoustic accuracy of calculated noise levels, of following the advice contained within the Working Groups' Position Paper (GPG) [1].

The GPG provides a series of Toolkits designed to assist EU Member States (MS), and their designated competent authorities, fulfill their obligations under the Environmental Noise Directive (END) [2]. The GPG Toolkits provide guidance on possible steps to be taken, or assumptions to be made, when all of the data that MS need in order to undertake the large scale wide area noise mapping required by the END is lacking either in coverage or in detail.

Whilst the GPG provides practical advice on decision-making in the absence of the required data, currently it provides no corresponding indication of the acoustic accuracy implications of making these decisions. This could result in the MS making decisions which result in unquantified levels of uncertainty being introduced into the mapping process .In this case both MS and the EU Commission will be uncertain about the accuracy and robustness of the results of noise mapping, even when the methodology used is well documented. A second consequence, possibly of equal importance, resulting from this lack of acoustic guidance within the GPG is that MS with a data shortfall are not provided with any help to make informed decisions on the relative importance of the various datasets which would help them focus their resources in the procurement of missing or inadequate data.

DEFRA's project was aimed at quantifying the effects on acoustic accuracy in strategic noise map results of adopting the advice in the present version of the GPG. This was focused on road traffic noise for the time being. The analysis was carried out using the XPS 31-133 calculation method which is the recommended Interim Method for the first round of END noise mapping in 2007.

The project also aimed to provide practical advice and guidance on the potential acoustic accuracy implications of following the advice within the GPG Toolkits, and thus help to inform MS, competent authorities and the EU Commission as to the robustness of the results submitted in 2007 under the END framework.

It should be kept in mind that testing the sensitivity of the Interim Method for variations in the input is only one part of the complete set of uncertainties that need to be considered when looking into the levels of uncertainty in noise mapping [3]. The context in which the acoustic accuracy of the GPG Toolkits should be seen and the interpretation of results in terms of requirements for noise mapping data are discussed in further detail in [4].

THE GPG TOOLKITS CONSIDERED

The toolkits that were studied from the current GPG are:

- Toolkit 1: Road traffic flow;
- Toolkit 2: Average road traffic speed;
- Toolkit 3: Composition of road traffic;
- Toolkit 6: Building heights;
- Toolkit 7: Obstacles;
- Toolkit 8: Cuttings and embankments;
- Toolkit 9: Sound absorption coefficients for buildings and barriers;
- Toolkit 12: assignment of population data to residential buildings.

The new GPG Toolkits developed in this project, presented in the following section, were tested as well.

In respect of Toolkit 12 accuracy symbols cannot be provided in terms of dB(A) values, since the application of this Toolkit does not have any bearing on the results of noise calculations.

NEW GPG TOOLKITS PROVIDED

As a result of the project a new set of Toolkits have been proposed for insertion into version 2 of the GPG. These additional Toolkits are:

- Toolkit 17: Road surface type;
- Toolkit 18: Road junctions;
- Toolkit 19: Road gradient;
- Toolkit 20: Ground elevation close to the source;
- Toolkit 21: Ground surface type;
- Toolkit 22: Barrier height.

The starting point for the proposed additional GPG Toolkits was that they would be independent of the noise calculation method used and are in conjunction with existing guidance provided by the GPG version 1 and related work such as [5]. An exception has been made for Toolkit 17, Road surface type, which requires extra guidance on texture depth for noise calculations according to de British CRTN.

A description of the background for the new toolkits is given in the following sections.

Toolkit 17: Road surface type

An important parameter in road traffic noise calculations is the reference road surface. This is the most commonly used road surface and also this is the road surface where most of the measurements have been carried out during the development of the calculation methods. An investigation across Europe shows that the reference surface in most cases is dense asphalt concrete 0/8, 0/11, 0/16 or a stone mastic asphalt 0/11.

In cases where the acoustic road surface properties are unknown, undertaking measurements would seem to be the most straightforward and accurate way to obtain road surface data. However, in most cases this is likely to be an expensive option. Therefore, further tools are provided within this Toolkit for situations where the physical properties (chipping size, porosity, type of pavement) of different road sections are known and when general information on road surface type is available, for instance from visual inspection. Another suggestion provided is to use a classification based on the function of the road and assign the most common road surface type to each class. All road surface corrections provided are independent of the traffic composition but for porous asphalt a distinction has been made between low and high vehicle velocity.

Toolkit 18: Road junctions

Several calculation methods used across the EU, including the Interim Method, provide a means of modeling traffic light controlled junctions and similar situations that create decelerating and accelerating traffic.

This Toolkit provides guidance on how to deal with such situations and to assign the traffic flow types to the road sections concerned.

Toolkit 19: Road gradient

In a noise mapping context it is generally assumed that road gradient information is derived from the underlying ground model, by 'draping' the road segments over the ground model to derive road height, and from that gradient information.

In practical situations when the full detail of the ground model may not be available, local variations in the road height may not be known in sufficient detail and hence road gradients will also be unknown. For cases when a (digital) ground model is not available, this Toolkit focuses on the location of hills, and more locally on the location of road sections connecting depressed or elevated road sections.

Toolkit 20: Ground elevation close to the source

Although many sections of road or railway will not have significant gradients, the noise propagation from these sources may be significantly influenced by variations in ground elevation close to these sources. This Toolkit gives guidance for cases when a ground model is not available in full detail and ground height variations have to be derived e.g from. paper cross-sections or the location of embankments.

Toolkit 21: Ground surface type

Practically all advanced noise calculation methods include some means of including ground attenuation Therefore, the attribution of ground as being either reflective or absorptive, or hard, soft or intermediate, will have an effect upon the total calculated noise level at the receptor points. This Toolkit provides tools to assign ground surface attributes to surfaces, using either a land use classification or by distinguishing rural, suburban or urban areas.

Toolkit 22: Barrier height

Small errors in the height or position of purpose-built barriers are generally more important than errors in the height or position of other objects in a noise model. Normally the barrier height should be determined preferably up to a precision level of 0.5 metre. However, for a noise mapping project of a large area, this level of detail may be unattainable. In such cases, this Toolkit provides default barrier heights.

TESTING METHODOLOGY FOR QUANTIFYING THE GPG ACCURACY SYMBOLS

In order to quantify the accuracy symbols used in the toolkits in Version 1 of the GPG, and also to help develop practical guidance on the acoustic accuracy implications of using these toolkits, the testing methodologies developed under this research project have been run using the XPS 31-133 calculation method.

Different approaches were chosen for testing the geometric and the non-geometric aspects as identified in Table 1.

The effects of using Toolkits 1 and 12, which provide guidance on factoring traffic flows and assigning people to properties, are independent of the noise calculation method. These toolkits have been considered separately.

Table 1: different aspects that were studied

Non-Geometric aspects	-Vehicle velocity -Traffic flow -Road inclination -Road surface type
Geometric aspects	-Ground surface type -Barrier height -Obstacles -Cuttings/embankments -Building absorption coefficients -Ground elevation -Building height
Others	-Population data -Factoring traffic flow

The accuracy symbols in the GPG Toolkits were then quantified by determining the 95 % confidence interval of all simulated noise levels.

NON-GEOMETRIC TESTING

In order to test the error propagation in the non-geometric aspects of the XPS 31-133 method, Monte Carlo analysis software tools have been developed to run scenario testing against the XPS 31-133 calculation method for assessing the source emission power level. Further details on the background and development of the tools are presented in [4].

The results of the analysis is provided in histograms which define the probability distribution of the output allowing for the calculation of statistical parameters such as standard deviation and variance. In addition to viewing the tendencies of the model with respect to errors, the method allows for stepped transitions in calculation methodology.

As there are a multitude of possible combinations of input parameters for which uncertainty analysis may be carried out, it is important within any study to first identify a limited number of typical situations, from across the range of possibilities, and to investigate them in order to assess the type of response generated.

For this reason, two realistic traffic scenarios have been selected for this part of the uncertainty study - the high noise case and the low noise case. This approach is similar to that taken by Lam and Tam [6].

The values of the parameters for each case are listed in Table 2. The results obtained from these two scenarios give a good indication of the potential decibel error variation for different traffic scenarios in between.

After ranking of the most significant input parameters, Monte Carlo Simulations were run varying these input parameters simultaneously. After assessment of the resulting uncertainty in the calculated noise levels, the results were compared with the single-parameter tests.

An outline of the non-geometrical testing is given in figure 1.

Table 2: high and low noise case for Monte Carlo Simulations

	Scenario	
Aspect	**High noise case**	**Low noise case**
Traffic flow	Light - 3000 veh/h Heavy - 1000 veh/h	Light - 285 veh/h Heavy - 15 veh/h
Vehicle velocity	Light - 108 km/h Heavy - 108 km/h	Light - 50 km/h Heavy - 50 km/h
Flow type	Pulsed Decelerating	Pulsed Decelerating

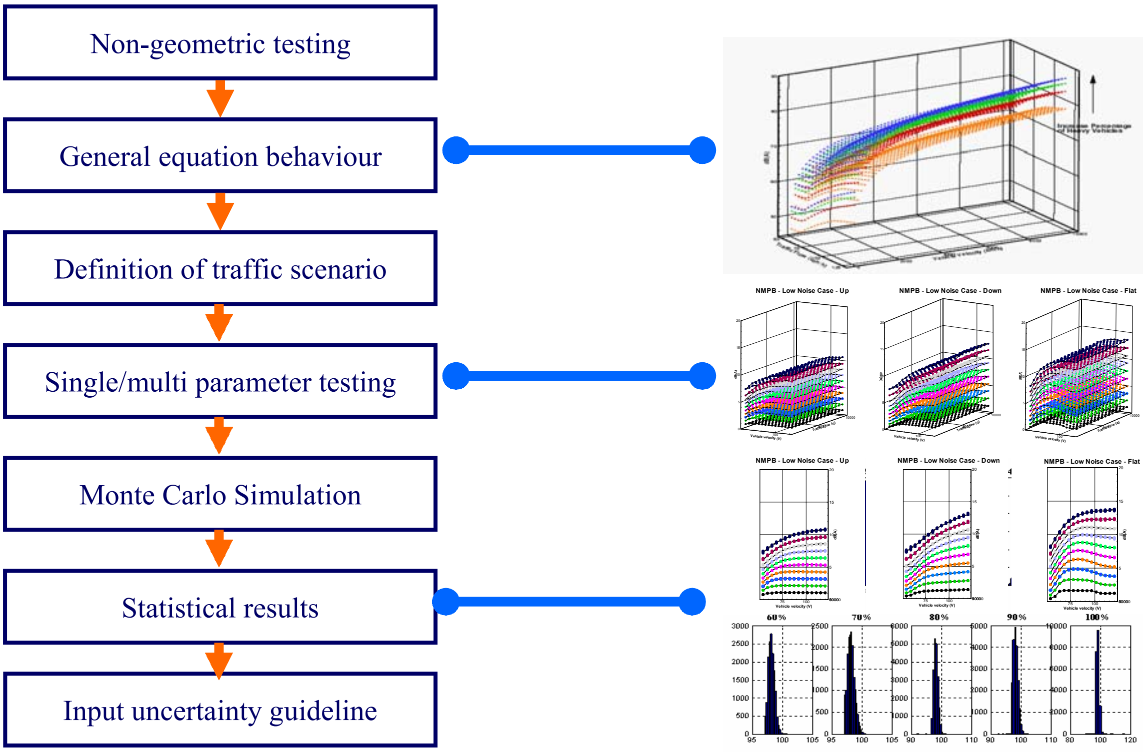

Figure 1: Outline of non-geometric testing of XPS 31-133

GEOMETRIC TESTING

Analytical analysis techniques can be used to assess uncertainty propagation where there is a direct relationship between the input data and the result produced from the calculation method used. However, when the accuracy of results depends upon a number of variables which include location information, and hence depend upon the actual geometry, an analytical approach becomes much more complicated and is not an option within the confines of this research project. As an example, the uncertainty propagation due to building height change will vary with change in building height, but also in a second dimension as the location of that change in building height varies within the geometry of the model.

For this reason an alternative approach has been used to test the input data with a geometrical aspect. The accuracy implications of such datasets have been examined by the use of a series of test maps, starting with a situation where input data is very detailed; this is known as the crisp model. Subsequently, the level of certainty is decreased stepwise, according to the tools in the GPG Toolkits to produce a series of metamodels. Each metamodel is a copy of the crisp model for which the detailed data within the crisp model, for a particular dataset or attribute, has been reduced in quality, or simplified, in line with the likely effects of using a particular option provided in a GPG Toolkit .

The crisp model and metamodels were then calculated using noise mapping software packages (Predictor and LimA were used), to produce a series of grid results. The results sets have then been analysed to assess the uncertainty in the results from the metamodels, compared to those from the crisp model.

For each input parameter under investigation a number of metamodels were produced in order to create a spread of uncertainty. Each was then calculated to produce a series of uncertainty propagations and finally the series of results were analysed together against the crisp model results to estimate the impact upon the accuracy which has been introduced.

This method is conceptually quite simple, and by utilising GIS tools to manage the step changes in input parameter data it was a straightforward exercise to develop the necessary metamodels. However, a significant downside was the time taken to run each series of grid calculations required to achieve a spread of results for each input uncertainty. For this reason it was only possible to carry out between 3 and 18 scenarios for any one input parameter under investigation. The number of scenarios tested has varied due to the design of the specific tests required for each aspect under consideration. It is considered that this has not lead to definitive results. However, it is thought that it has provided an understanding of the uncertainty propagation suitable to inform the use of the GPG Toolkits.

Development of the test models

A representative test noise map was required to set as the base crisp model. The model needed to be produced with sufficient relevance, and a large enough number of assessment points to enable a spread of typical geometrical scenarios to be assessed simultaneously within one calculation run, with the assessment of results taken across the whole model. The noise map area needed to include the following items that are relevant for noise computation and assessment of noise levels:

- Urban and suburban cases;
- With and without barriers/embankments;
- With motorways, secondary roads and different types of urban roads;
- In flat terrain and hilly environment;
- With demographic data of different kinds.

Consideration was given to utilising existing noise simulation models from work previously carried out by members of the project team. Consideration was also given to the creation of a specific geometrical dataset, amalgamated from other available data, in order to build a crisp model with complete notional datasets for all the input attributes to be tested.

It was decided that the model should be composed of several sub models each having a sufficiently high level of detail, making it possible to test the recommendations in the GPG Toolkits.

The crisp model was built up from a number of sub areas, for which the data has various origins. Road traffic flow was partly determined by automotive traffic counts (with distinction between light vehicles and heavy vehicles) and partly by traffic flow modeling. In certain sub areas, buildings have been generated from laser altimetry whereas in other sub areas, they were digitized from scale 1:1000 maps and building height was taken from on site visual inspection.

The total area is approximately 6 km by 4 km which provided a calculation grid of approximately 240,000 points. The following figure gives 3-dimensional impressions of the four sub-models used for the geometrical testing of the Toolkits.

Figure 2: Sub-models for the geometrical testing of the toolkits
(top left: Sub -urban motorway, top right: Urban traffic,
bottom left: Hilly terrain, bottom right: Detailed building height)

CONCLUSION

This research project set out to develop and test six additional toolkits, quantify the accuracy symbols within several of the GPG Toolkits, and to develop practical guidance for Member States on the implications on the calculated decibel levels of using the Toolkit recommendations.

Two approaches to error propagation testing have been developed, one based upon Monte Carlo tools for non-spatial source emission levels, the other based upon mapping model calculations for propagation effects.

The non-geometric Monte Carlo tests have shown that errors in the vehicle speed, both for light vehicles and heavy vehicles, propagate through the XPS 31-133 source model to cause the largest associated decibel errors. For the geometrical part, the model has the strongest sensitivity to inaccuracies in ground elevation and road cutting depth. The use of fairly representative default values for ground surface type, building height and absorption coefficient, to be determined for the mapping area, will keep the decibel errors generally within acceptable limits for strategic noise mapping.

These results have been further utilised to form the basis of the GPG Toolkits with quantified accuracy statements.

The results of the analysis have also been used to help develop practical advice on data requirements for noise mapping. This advice covers data quality, data sourcing and specification for data procurement as presented in [4].

It is recommended that further testing of the remaining GPG Toolkits is carried out and that the sources of uncertainty for noise mapping input datasets is explored. Additionally, quantifying the sources of uncertainty within the calculation methods itself and the software tools implementing them would give useful guidance on how to see the acoustic implications of using the GPG Toolkits in the perspective of a noise map's total level of uncertainty.

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