**The Department for
Environment, Food
and Rural Affairs (DEFRA)**
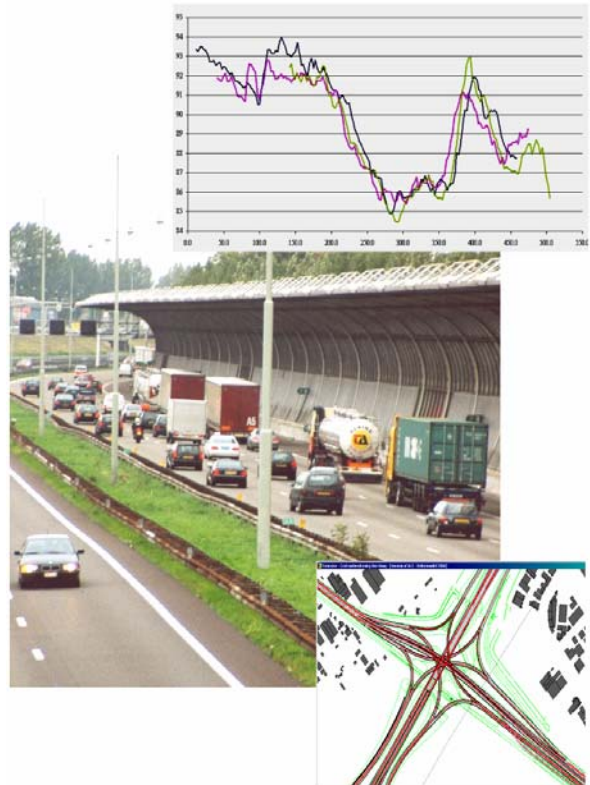
**Research Project NANR 93:
WG-AEN's Good Practice
Guide And The Implications
For Acoustic Accuracy**

Final Report:

**Data Accuracy
Guidelines for
XPS 31-133**

Document Code:
HAL 3188.3/8/2
DGMR V.2004.1300.00.R012.1

May 2005

HEPWORTH ACOUSTICS
noise and vibration consultants

dGm^R

ACUSTINET
Ingeniería en acústica y ruido ambiental

The Department for Environment, Food and Rural Affairs (DEFRA)

Research Project NANR 93: WG-AEN's Good Practice Guide And The Implications For Acoustic Accuracy

Final Report:

Data Accuracy Guidelines for XPS 31-133

Document Code:
HAL 3188.3/8/2
DGMR V.2004.1300.00.R012.1

May 2005

Hepworth Acoustics Ltd
DGMR Industrie, Verkeer & Milieu B.V.
Acustinet SL

The Department for Environment, Food and Rural Affairs (DEFRA)

Research Project NANR 93: WG-AEN's Good Practice Guide And The Implications For Acoustic Accuracy

Main Contributors

Simon Shilton CEng, BEng, MIOA, MAES
Head of Software & Mapping
Hepworth Acoustics Ltd

Hans van Leeuwen
Division Manager
DGMR Industrie, Verkeer & Milieu B.V.
DGMR Consultants for traffic, environment and software

Issued by

....
Simon Shilton

Checked by

....
Peter Hepworth

Hepworth Acoustics Ltd

5 Bankside
Crosfield Street
Warrington
WA1 1UP
Tel: 01925 579100
Fax: 01925 579150
Email : simon.shilton@hepworth-acoustics.co.uk

Ref: 3188.3/8/2

Final Report:

Data Accuracy Guidelines for XPS 31-133

Hepworth Acoustics Ltd
DGMR Industrie, Verkeer & Milieu B.V.
Acustinet SL

1. Executive Summary

1.1 Project

Defra has let a research project in support of the European Working Group – Assessment of Exposure to Noise (WG-AEN) to determine the likely effects on the acoustic accuracy of the advice contained within the Working Groups' Position Paper "Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise exposure" Version 1 December 2003 (GPG).

The key objectives of the project are summarised as follows:

- Provide potential additional GPG Toolkits for issues not currently covered within existing guidance for EU Member States (MS) dealing with the Environmental Noise Directive (END);

   o Devise six new toolkits for: road surface type, road junctions, road gradient, ground surface elevation, ground surface type and barrier height; in a format compatible with the existing GPG Toolkits;

- Quantify the accuracy symbols within Version 1 of the GPG when Toolkits 1, 2, 3, 6, 7 and 8 plus the new road surface Toolkit, are used in conjunction with CRTN and the recommended Interim Method for roads XPS 31-133;

- Provide practical guidance on the acoustic accuracy implications of following the recommended toolkits within the WG-AEN GPG;

- Provide practical assistance to MS and professionals dealing with data management and procurement across the EU in relation to the END;

- Liaise closely with WG-AEN to ensure that the views and requirements of the EC and member states are taken into consideration during the project.

1.2 Data Accuracy Guidelines for XPS 31-133

Across the EU Member State the requirements for the END are beginning to drive a series of projects to develop wide area noise maps to cover the agglomerations and major transport links which must be reported back to the Commission.

One of the key aims of this research project is to help develop practical guidance on the quality of data required for noise mapping purposes under the END. The aim of

this guidance is to help quantify and grade existing data available to each responsible authority and also to help to form the basis of a technical specification for a data capture programme, if this is to be undertaken to fill gaps in the existing data available.

This report presents a series of discussions, tools and recommendations based upon the results of the error propagation analysis carried out within this research project. The aim has been to provide practical guidance which presents the analytical results in a real world context to enable Member States, Competent Authorities and mapping practitioners to use the results.

1.3 Conclusions

Consideration of the requirements for strategic noise mapping has been discussed, along with the range of input datasets required, and how the results of the error propagation testing can inform the use and manipulation of source data.

An overview of the accuracy of the datasets required for XPS31-133 has been set out, along with a discussion of some of the decisions which are likely to be required. Where the investigations of this research have produced results to inform these decisions, they have been reported in context to assist with the process.

This report represents the culmination of the research project at this stage, as well as presenting much practical experience from within the project team.

With respect to the non-geometrical part of XPS 31-133, the quality of a noise map is improved mostly by a reduction of the uncertainty in the vehicle speed. For the geometrical part, attention should be paid to the accuracy of building and barrier height, road embankment height or cutting depth rather than to the horizontal position and reflection properties.

Contents

2.   Introduction

In its capacity of support for the chair of the European Working Group – Assessment of Exposure to Noise (WG-AEN), 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 "Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure" Version 1 December 2003 (GPG).

WG-AEN was originally set up at the end of 2001 with a two year remit, which included the development of the guidance within the GPG. At the start of 2004 the WG-AEN received a new one year mandate and revised terms of reference, which included a requirement to collate and assess responses to the content of the GPG and produce version 2 before the end of 2004.

The GPG sets out a series of Toolkits which can be used by EU Member States (MS), and their designated competent authorities, whilst fulfilling the requirements of Directive 2002/49/EC, the Environmental Noise Directive (END). The Toolkits within the GPG are designed to provide guidance on potential steps to be taken, or assumptions to be made, when the dataset available to the MS falls short of the coverage or detail required for the large scale wide area noise mapping required by the END.

Whilst the GPG provides practical advice on decision making in the absence of detailed data, there is currently no corresponding indication of the acoustic accuracy implications of making the decisions. This will result in the MS making choices where the level of resulting uncertainty introduced into the process is unknown, and therefore both the MS and the EU Commission will be uncertain about the potential accuracy and robustness of the results, even when the methodology is documented and the process followed the advice within the GPG. A second consequence, and possibly of equal importance, is that this lack of acoustic guidance within the GPG does not help MS with a data shortage make informed decisions on the relative importance of the various datasets which would help focus (finite) resources in the procurement of missing data.

Defra wish to study the consequential acoustic accuracy in strategic noise map results of adopting the advice in the present version of the GPG, focused at this point on road traffic noise. This project aims to result in practical 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.

HEPWORTH ACOUSTICS *noise and vibration consultants*	1	dGm^R	ACUSTINET

The guidance should also help to assist MS to produce their own guidance regarding the relative importance of the various datasets required to carry out END compliant noise mapping, and thus help to manage any budget available for data procurement towards the datasets that will provide the most benefit to the acoustic accuracy of the results.

2.1   Scope of Research Project

Having identified techniques and methodologies for investigating the error propagation of the noise mapping system, carried out the error propagation testing and presented the results, this report draws the results of the testing together to provide a practical presentation of the implications of the results to be viewed alongside the GPG Toolkits with quantified accuracy statements presented in another report associated with the research project.

One of the main aims of this research was to present practical guidance and interpretation of data sourcing and accuracy issues which are highlighted from the work within this research project.

This report presents a practical reference to help in assessing the quality of input dataset for use in noise mapping projects using the XPS 31-133 calculation method. These accuracy constraints have been presented at levels to help manage the noise calculation result quality.

3. Assessing the Requirements for Noise Mapping – XPS 31-133

The guidance on data quality requirements for large area noise mapping is set out below. It is considered appropriate that this guidance provides an overview of the requirement for the noise maps, and an outline of aspects to be considered, along with the actual dataset design advice. This is to ensure that the guidance is seen as a whole, rather than viewed in isolation from the context to which it applies.

3.1 Background to the recommendations

The European Commissions Directive 2002/49/EC, the Environmental Noise Directive (END), sets out an aim for protection of the environment and for health within the EU. This is to be achieved by Member States (MS) developing Community Measures (CM) to improve the quality of life. The proposed means of displaying commitment to, and management of, these CM is by the development of Noise Action Plans (NAP).

In order to help produce NAP, assess the extent of the noise impact, and inform strategic policy making, it is required that the MS produce Strategic Noise Maps some 12 months before the Action Plans must be submitted.

The manner in which the results from the noise maps must be described is set out, in 5 dB(A) wide bands, of numbers of people affected, for agglomeration areas of more than 250,000 inhabitants in 2007, and more than 100,000 inhabitants in 2012.

3.2 Requirements of Noise Mapping for the END

In order to define recommendations for data standards suitable for noise mapping in the context of the END, it is appropriate to first review the end uses of the noise mapping exercise. As the end uses will define the requirements of the maps and these requirements help to shape advice on appropriate data to use.

For the CM and NAP to have a realistic chance of success, they will have to be compatible with other environmental policies, as well as socio-economic policies, and not produce negative impacts on other aspects of the community. It could also be deemed appropriate that the noise maps developed should be relevant for the subsequent use within the development of NAP, and possibly used to demonstrate the potential benefits of proposed CM. To meet these ends, the noise maps will need to be repeatable, sustainable and compatible with other technical disciplines utilising the same information.

NAP can be viewed as the principle outcome from the END. They are to be developed to help inform and guide strategic policies and decision making. The term 'strategic' refers to high level decisions regarding overall noise management which will be made based upon the results of the noise exposure assessment process, of which the noise maps form a part. The strategic noise maps required are to inform high level policy making, based upon robust results, it does not infer that accuracy is optional as this would lead to erroneous decisions being made.

The mapping required will need to cover wide areas of land, and at a large scale, in order to collect the resolution of information required for action planning. The term 'scale' refers to the geographical accuracy of the model and noise data produced. A larger or higher scale is more detailed, and a smaller or lower scale is less detailed.

It is usual for receivers to be based upon a grid with the spacing between them at a satisfactory distance to result in data which are both fit for the desired level of geographical analysis, and which are suitable in comparison to the accuracy of the input data used to create the model. For example, UK Ordnance Survey digital map data is often supplied at a scale of 1:1250. Assuming all other input data was supplied at the same scale; this would then restrict a suitable output noise grid scale to a similar level. Whilst it is possible to amalgamate results into a lower scale dataset, perhaps for a regional or national perspective, increasing the scale through interpolation in an attempt to derive more detailed results will invariably introduce errors which dilute the accuracy of the results generated.

This issue of scale leads onto a question of accuracy, both of input data, but more importantly on the resulting noise levels calculated. Accuracy of the resultant value in an absolute sense for a process is generally unimportant when only comparison studies are being carried out, or the identification of change is important, or when there are no targets, limits or other absolute milestone values.

Accuracy is generally important when the assessment being undertaken is linked to targets, where comparison with limits is being undertaken, or when post result analysis is to be carried out to abstract results for other purposes. For example, the process of reporting results in noise bands can be described statistically as being divided by crisp boundaries into sets.

If the issue of whether the END requires accuracy is now addressed we can see that the requirements are:

- Reporting of limit values, absolute targets,

- Reporting of numbers of people in discrete 5 dB wide bands,

- Noise maps produced to inform development of Noise Action Plans, which means assignment of budget,

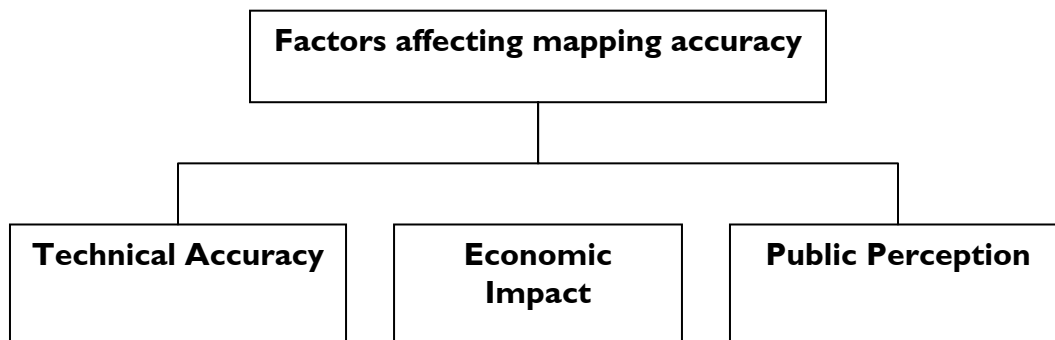- Noise map results to be post processed and linked to numbers of people.

The future use of the maps and their results could well include:

- Design of noise mitigation measures, which means public money expenditure,

- Post processing of the number of people information to assess noise exposure across economic, social and ethnic groups to assess potential social exclusion issues.

All of these required or potential uses rely upon the results of the mapping process being accurate in an absolute sense, not just a relative sense. For this reason, understanding the sources and magnitude of potential errors within the noise mapping process is a key factor in beginning to develop a strategy for a response to the END which will be able to deliver all that is required of it; i.e. fit for purpose.

3.3   Achieving accuracy suitable for the END

There are several factors which affect the level of accuracy that could be seen as appropriate for the results of the noise mapping process within the END. These could be considered as technical accuracy, economic impact and public perception.

```
┌─────────────────────────────────────┐
│   Factors affecting mapping accuracy │
└─────────────────────────────────────┘
          │
 ┌────────┼────────────────┐
 │        │                │
┌──────────────┐ ┌──────────────┐ ┌──────────────────┐
│  Technical   │ │   Economic   │ │ Public Perception│
│  Accuracy    │ │    Impact    │ │                  │
└──────────────┘ └──────────────┘ └──────────────────┘
```

3.3.1   Technical Accuracy

Stated simply, this comes down to whether the results are sufficiently accurate that dividing them into crisp 5 dB(A) wide sets is an appropriate process. This use of the results implies that we should have absolute accuracy within 2 dB(A) of the actual value.

3.3.2 Economic Impact

Over the past few years the economic cost/benefit of noise levels and noise mitigation has been investigated. This research can help to inform us of the potential cost to society of the assessment and analysis producing accurate results.

The "Valuation of Noise" Position Paper of WG HSEA, 21 November 2003 states:

> *"For road transport, the (interim) use of the median value change in noise perceived by households of 25 € per dB (L_{den}), per household per year. The validity range of this interim value is between 50/55 L_{den} and 70/75 L_{den} and it should be adjusted as new research on the value of noise becomes available".*

This cost is said to apply at all initial noise levels, and regardless of the size of any change brought about.

Work by the Danish Department of the Environment (Miljøstyrelsen) states that, for houses exposed to levels greater than 55 dB, the house price:

- declines by 1.2% per dB near "ordinary" roads, and

- declines by 1.6% per dB near motorways.

It should also be considered desirable to achieve accurate and robust results simply because the European community will be investing so heavily in the process of noise mapping, noise actions plans, and mitigation. With 450 million EU residents, and possibly 60% within agglomerations, the initial noise maps may cost 0.2 to 1 € per inhabitant, before additional expenditure on the subsequent work.

3.3.3 Public perception

Although this is apparently not the most obvious reason for accuracy, the END noise maps, and subsequent action plans, are probably the highest profile activity that the acoustics and noise control community has carried out, in the public eye.

Based upon previous experience, the generation of these results will probably lead to articles within the television and print media. Articles may compare adjacent towns, states or countries.

In order that the industry's credibility is upheld, good results and robust recommendations for action should be a desirable aim.

3.4 Sources of Uncertainty in Noise Modelling

Isukapalli and Georgopoulos[1] set out 4 key areas to be studied in order to understand how and where uncertainty arises within a modelling system designed to reproduce a real world environment:

1. estimation of uncertainties in model inputs and parameters (*characterisation of input uncertainties*);

2. estimation of the uncertainty in model outputs resulting from the uncertainty in model inputs and model parameters (*uncertainty propagation*);

3. characterisation of uncertainties associated with different model structures and model formulations (*characterisation of model uncertainty*), and

4. characterisation of the uncertainties in model predictions resulting from uncertainties in the evaluation data (*i.e. if you are validating the calculations against measured levels, how uncertain are your environmental noise measurements?*).

For each of these four areas of potential uncertainty it is possible to discuss some of the practical measures and processes which could be adopted as part of the noise mapping process in order to understand the magnitude of uncertainty in the results.

Note that the current project is only investigating uncertainty propagation through the XPS 31-133 and CRTN calculation methods, via two different sets of step changes, (1) in line with the GPG Toolkit steps, both individually and in combination; and (2) as individual input parameter variations across the range of probable input values, both individually and in combination.

The following scheme gives a graphical representation of how the different sources of uncertainty interact – see Figure 3.1.

---

[1] "Computational Methods for Sensitivity and Uncertainty Analysis for Environmental and Biological Models" SS Isukapalli and PG Georgopoulos, National Exposure Research Laboratory, U.S. Environmental Protection Agency, EPA/600/R-01-068, Dec. 2001.
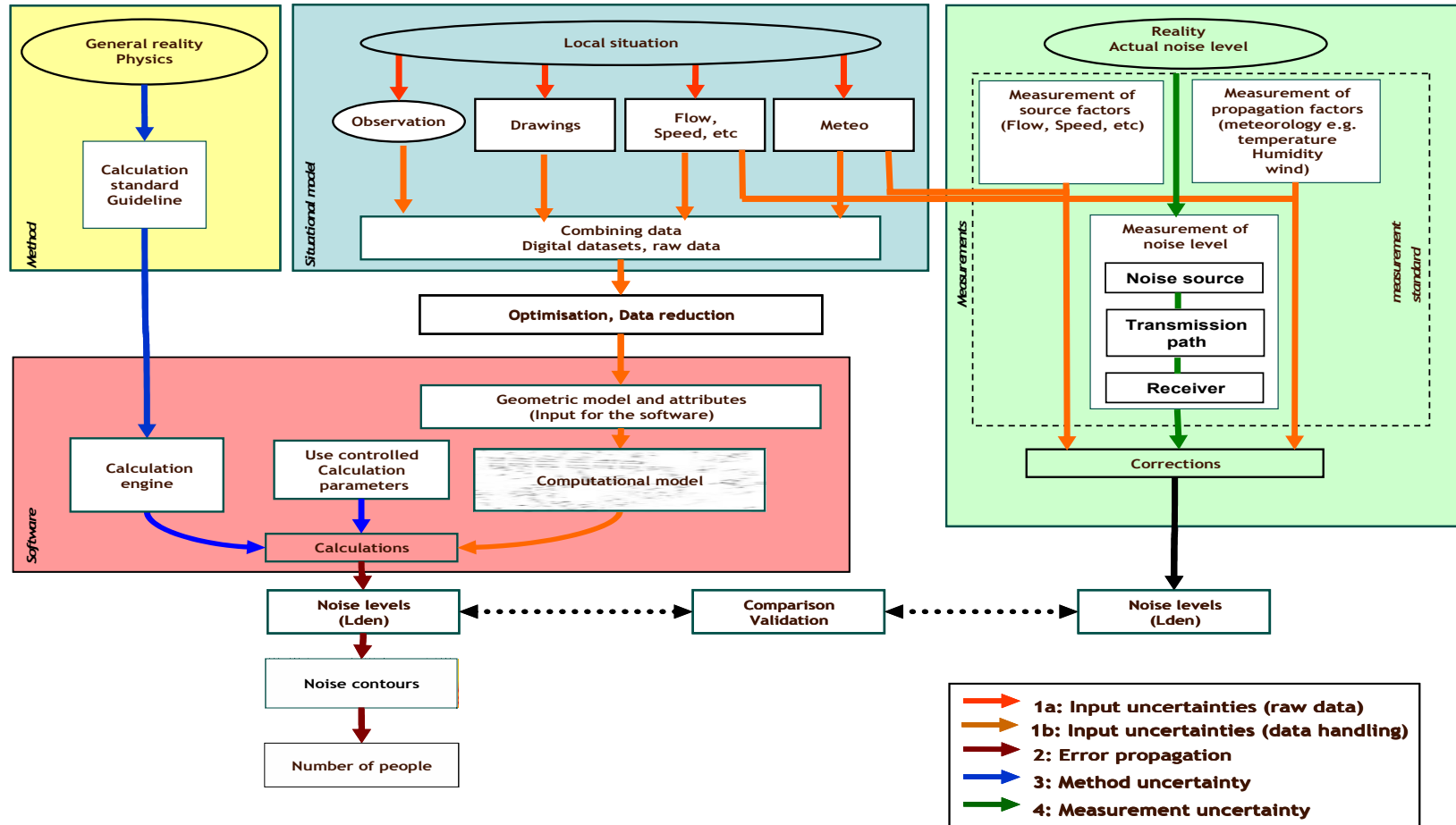
Figure 3.1: Uncertainty flow chart.

Below is a brief discussion of each of the four factors listed above.

3.4.1 Input Uncertainties

Characterising input uncertainties would involve a study of each of the various types of data required to construct a finished noise map. These uncertainties arise from various sources including: measurement; management, factoring and reporting of the actual captured information prior to reporting. To form an understanding for each type of input dataset there would probably need to be liaison with domain specialists such as data providers, owners and managers, in order to seek an understanding of how the uncertainties of the input values are distributed. There would also need to be detailed analysis carried out to quantify the scale and distribution of these uncertainties in the delivered dataset.

MS and noise mapping agents should be aware of the need for *characterisation of input uncertainties* but it will possibly vary from country to country, dataset to dataset, and each data owner or manager will need to be interviewed regarding this aspect. When known, this information can be used in combination with the results from this current project to help understand how these input uncertainties will affect the final result from the model.

In this current project, it has been assumed that each input dataset has a normal distribution of uncertainties.

3.4.2 Uncertainty Propagation or Sensitivity

Uncertainty Analysis (UA) allows the assessment of model response uncertainties associated with uncertainties in the model inputs. Sensitivity Analysis (SA) studies how the variation in model output can be apportioned to different sources of variations, and how the given model depends upon the information fed into it.

The work within this current project is centred on assessing the means by which uncertainties, error or assumptions within the input datasets of noise maps propagate through the calculation tools to produce uncertainties or errors in the decibel results obtained. The recommendations set out within the Toolkits proposed for the GPG v2 refer to the XPS 31-133 Interim Method.

Some results specific to the use of the UK CRTN method have also been produced within this study. However, there may be a requirement for a similar exercise for other national methods to be used within the END if such information is not currently available.

3.4.3 Model Uncertainties

The *characterisation of model uncertainty* is a role for the owners and developers of the noise models being used, and as the current first round of END submissions are to use

existing methodologies then it follows that the methods are to be used "as is". Should comparative studies of the national methods be published, or error propagation analysis carried out for each of them, it could help to determine a means by which "equivalence" is demonstrated for the END.

The second aspect of the model uncertainty is the issue of how the documented standard is transposed from a paper document into a 3D noise calculation tool, and how the tools additional simplifications, efficiency techniques and assumptions introduce further uncertainties into an uncertain methodology in order to create usable real world calculation times.

For this reason, it may be appropriate to discuss some of the aspects of noise mapping tools which may make them suitable for large area agglomeration mapping, and reduce the risk of additional uncertainties being introduced:

- Documented compliance with the calculation methods to be used;

- Proven record of use in city sized projects and larger;

- Flexible data interoperability, and compatibility with 3D datasets without compromising integrity of data;

- Ability to enable multi-user working on a project in order to promote team working, and shared decision making,

- Scalability and means of calculating large areas in a seamless coherent manner which avoids discontinuity of results;

- Should be commercial products, as this helps to ensure compatibility and long term reusability.

3.4.4   Uncertainty of Evaluation Data

The issues surrounding uncertainties in environmental noise measurements have been researched in detail by Craven & Kerry[1] whose work suggested that for short term measurements you were doing well if repeat measurements are within 5 dB(A) at the same site, for the same source, on different days.

Having said that, the basis of the END submissions is long term values of L_{den} and L_{night}. Where "long term" generally means "annual average", or even "several year average" when meteorological effects are to be considered.

---

[1] "A Good Practise Guide on the Sources and Magnitude of Uncertainty Arising in the Practical Measurement of Environmental Noise" NJ Craven, G Kerry, DTI Project: 2.2.1 – National Measurement System Programme for Acoustical Metrology, University of Salford, October 2001, ISBN: 0-9541649-0-3

Work within the Harmonoise project has carried out long term monitoring exercises and compared them with calculations using the Harmonoise methodology. This work indicates that the uncertainties in the measured levels can be reduced if the measurements span over a year, and the meteorological and ground absorption factors are representative of a several year average.

3.5 Recommended technical specification for input datasets

The recent report "Imagine – State of The Art" from the EU Imagine Project stated the following:

> *"Accurate acoustical modelling of environmental noise, no matter how powerful a prediction tool may be, requires high quality input data, both for the geometric model and for the acoustical properties. The resulting quality of the noise calculation depends considerably on the quality of data pre-processing and on the efforts involved for accurate representation of the situation to be characterised by the noise calculation. As everywhere, it also holds true for any noise calculation program, that the output can only be as good as the input."*

This statement demonstrates that there is an understanding of the issue regarding the quality of input data affecting the results of the calculated noise levels. What is surprising is that only one reference could be found which actually tries to assign limits to the certainty of input information to the noise mapping process:

> *Draft German standard E DIN 44682 Sound Immission Maps:*

- *"The usual scale is 1:5,000 down to 1:10,000. NOTE 1: It may be useful to choose a scale of 1:1,000, 1:500 or larger where sound immissions distributed over a small area, or the efficiency of noise control measures at the source or along the propagation path, are to be represented to allow the preparation of development plans or individual plans considering individual buildings. Although this standard is not supposed to make specifications for small-area calculations, it should be ensured that for such representations, the data acquired for large-area sound immission maps in accordance with this standard may be used with the least possible additional expense"*

    - *"Basic topographical data may be drawn e.g. from:*
      (a)   digital models of the terrain;
      (b)   topographical maps with contour lines in steps of not more than 5 metres;
      (c)   heights of drain manholes;
      (d)   topographical data of streets, obtainable e.g. from the roads of highways department;
      (e)   in individual cases, own measurements;
      (f)   screens or barriers (heights of sources and adjacent screens/barriers

should be given with a relative uncertainty of less than 1 metre);
(g)   interpretation of aerial photographs.

*Slopes and break lines shall be recorded separately if they are of essential importance
to the sound propagation in the vicinity of areas requiring noise control."*

Following on from the work on single and multi-parameter input testing of XPS 31-133 Interim Method, it is not only possible to assign guidance to the selection steps within the GPG Toolkits, but also possible to draw up a proposal for a dataset specification suitable for the purpose of noise mapping in support of developing the END results and subsequent noise action plans.

The recommendations are presented in the subsequent sections, each outlining different aspects of the required dataset, or possibly different model objects.

Alongside the data object definitions, data accuracy recommendations are made, where possible. The approach to accuracy constraints is based upon the sensitivity testing carried out within this research project. The concept is to assign a "Group" reference to the supplied dataset, such that the potential error in calculations is understood.

- Group A is aimed to have very detailed input data. This group should be used for detailed calculations, and for validation.

- Group B is aimed to manage uncertainty in the input attributes to within limits which each produce less than a 1 dB error;

- Group C is aimed to manage the input specifications such that potential errors in each element produce less than 2 dB of error;

- Group D is aimed to manage the input specifications such that potential errors in each aspect produce less than 5 dB of error. **NOTE:** in some cases, for END mapping, use of the guidance within the GPG may result in lower levels of error than using the available data; and

- Group E is assigned when requested limits desired for Groups A, B or C cannot be met with confidence, in this case it is recommended that data quality is improved where possible by new data capture, or by using the guidance within the GPG, in preference to the data available.

It should also be noted that the multi-parameter sensitivity testing carried out has indicated that the compound effect of a number of parameters each in error, will result in a combined error of higher magnitude. For example, managing to contain each input dataset to fit within Group C, less than 2 dB per parameter variation, could lead to an overall calculated level with an uncertainty in the order of 5 dB.

4. Recommendations for input dataset requirements

In this section, the recommendations based upon the results of the error propagation analysis carried out within this research project for XPS 31-133 are presented.

4.1 Non-Geometric Aspects

1. Propagation error due to uncertainty in the input parameters in the XPS 31-133 methodology is found to be significant for some input parameters and traffic scenarios. The simulations show that the propagation error in XPS 31-133 is scenario dependent. This is because of the multiple functions used in the method for different traffic conditions and scenarios.

2. Uncertainty in the vehicle speed gives the largest decibel error in the calculated result. In general, the decibel error increases with the input magnitude. Therefore, for high input value, more accurate input data is required.

3. The decibel error due to multiple simultaneous input uncertainties is larger than those with a single input uncertainty. This also means in the case of multiple input uncertainties, the accuracy requirement for each input parameter will be higher than those with a single input uncertainty.

4. Table 4.1 below ranks the sensitivity of the decibel error in the calculated result to the uncertainty of the input parameter to noise emission calculation in a descending order. Two scenarios are presented which correspond to a high noise case (percentage of heavy vehicle greater than 30%) and a low noise case (percentage of heavy vehicle less than 30%).

Table 4-1: Order of merit for input parameters to noise emission calculation

Rank of important	Percentage of heavy vehicle (%HV > 30)	Percentage of heavy vehicle (%HV < 30)
1	Heavy vehicle velocity (HV)	Light vehicle velocity (LV)
2	Heavy vehicle flow (Hq)	Light vehicle flow (Lq)
3	Light vehicle velocity (LV)	Heavy vehicle velocity (HV)
4	Light vehicle flow (Lq)	Heavy vehicle flow (Hq)
5	Road gradient	Road gradient
6	Road surface	Road surface

4.2 Geometric Aspects

4.2.1 Source height

Due to the fact that the ground near the source is always considered acoustically reflecting, the sensitivity of the ground effect for source height variations is weak. It is of more importance if source height variations lead to varying diffraction effects by screening objects. A shallow cutting has more influence on the noise levels than a low embankment. However, if a barrier is placed along the road, the effects of an embankment increase up to those for a cutting.

4.2.2 Ground surface type

Using hard ground as a default ground type can lead to local inaccuracies of 10 dB(A). For suburban cases with mixed ground, the average error is in the order of 2 dB(A).

The accuracy of calculations can strongly be improved by distinguishing between urban, suburban and rural areas of by the use of polygons with a land use classification. Though extreme local errors may occur like in the case of hard ground by default, 95% of all noise levels will be within +/-1.5 dB(A).

4.2.3 Ground elevation

In hilly terrain, ground elevation variations may lead to diffraction effects and substantial inaccuracies of the ground elevation model will then lead to extreme associated errors in the noise levels.

4.2.4 Barrier height

The effects of inaccuracies in the barrier height have a local impact on the noise levels. Although extreme errors are found in the proximity of the barriers, the noise levels are generally within +/-2 dB(A) when the barrier height can be estimated within 1m.

4.2.5 Building heights

If the number of storeys is known for each building and if the default storey height is fairly representative for the mapping (sub)area, this will lead to a very accurate estimation of the building height. The general accuracy of the noise map is about 1.5 dB(A).

The use of a default building height for building types, for the whole mapping area or for sub areas, requires a good estimation of the average height in order to get sufficient accuracy on the calculated noise level.

4.2.6 Building and barrier absorption coefficients

The effect of reflections against buildings or other vertical surfaces is stronger in dense, urban areas than in suburban regions. The strongest effects are found behind the first row of buildings, where noise levels are relatively low.

4.3   Guideline

Table 4.2 below set out the recommendations for the uncertainty values to be used in order to assess the quality of an input dataset for noise mapping purposes, or where a data capture exercise is to be commissioned. Graphical representations of Table 4.2 are also presented – see Figures 4.1 and 4.2.

Table 4-2: Level of accuarcy required of the input parameters for different decibel errors in the strategic noise mapping. Road Traffic Data Attributes

	Traffic Flow	Group A 0.5-1dB(A)	Group B 0.5-1dB(A)	Group C 1-3dB(A)	Group D 3-5dB(A)	Group E >5dB(A)
Heavy Vehicle Flow (Hq)	Continuous Fluid	20%<	20-40%	40-90%	90-160%	>160%
	Non differentiated Pulsed					
	Pulsed Accelerated					
	Pulsed Decelerated					
Heavy Vehicle Velocity (HV)	Continuous	10%<	10-20%	20-70%	70-130%	>130%
	Non differentiated Pulsed					
	Pulsed Accelerated					
	Pulsed Decelerated	5%<	5-10%	10-30%	30-50%	>70%
Light Vehicle Flow (Lq)	Continuous	20%<	20-45%	45-100%	100-200%	>200%
	Non differentiated Pulsed					
	Pulsed Accelerated					
	Pulsed Decelerated					
Light Vehicle Velocity (LV)	Continuous	10%<	10-20%	20-65%	65-120%	>120%
	Non differentiated Pulsed					
	Pulsed Accelerated					
	Pulsed Decelerated	5%<	5-10%	10-40%	40-95%	>95%

	Factor	Group A	Group B	Group C	Group D	Group E
Source	Gradient Type (flat= >+2% - <-2%)	No error, sections <50m	No error, sections <100m	No info (up or down), sections <200m	No info (up or down)	No info (up or down)
	Traffic Flow Type	No error	Within 1 class	Within 1 class (continuous)	No info (continuous)	No info (continuous)
	Surface Type	No error, sections <50m	No error, use classes	≤1 class away	≤2 classes away	No info (dense asphalt)
	Road centreline (Vertical)	<0.5m	>0.5m - <1.0m	>1.0m - <2.0m	>2.0m - <5.0m	>5.0m
	Road centreline (Horizontal)	<1.5m	>1.5m - <4.0m	>4.0m - <8.0m	>8.0m - <15m	>15m

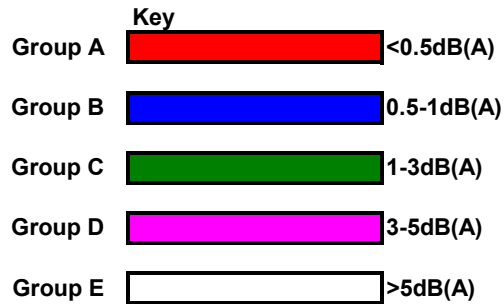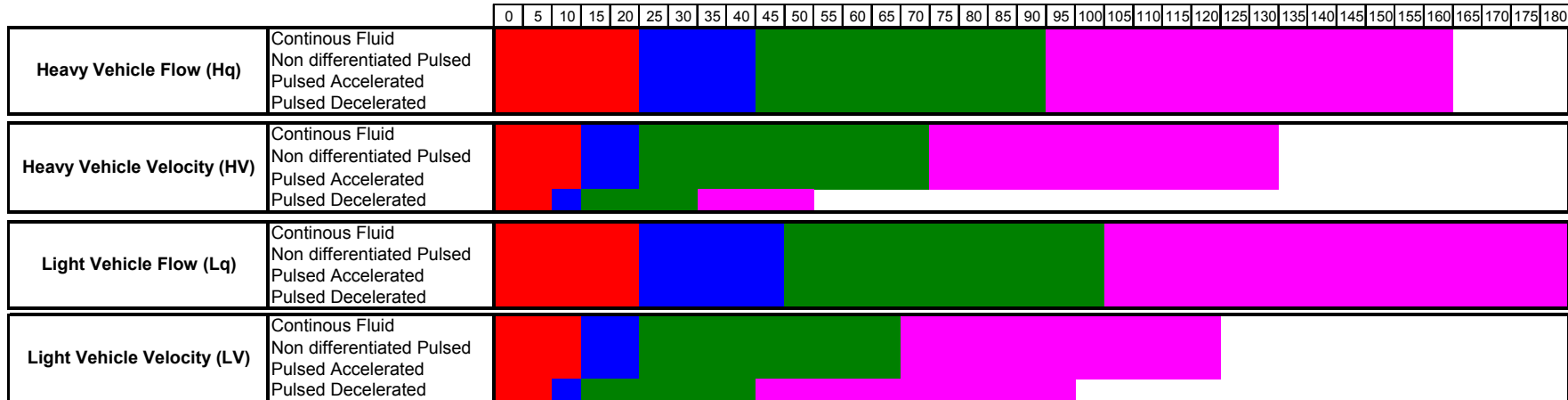|	Factor	Group A	Group B	Group C	Group D	Group E
Ground Model	Ground height, contours, TINs etc (Vertical)	<0.5m	>0.5m - <1.2m	>1.2m - <2.5m	>2.5m <5.0m	>5.0m
	Ground height, contours, TINs etc (Horizontal)	<1.5m	>1.5m - <4.0m	>4.0m - <8.0m	>8.0m - <15m	>15m
	Profile edges (Vertical)	<0.5m	>0.5m - <1.2m	>1.2m - <2.5m	>2.5m - <5.0m	>5.0m
	Profile edges (Horizontal)	<1.5m	>1.5m - <4.0m	>4.0m - <8.0m	>8.0m - <15m	>15m
	Equal height contour spacing (Vertical)	<1.0m	>1.0m – <3.0m	>3.0m - <8.0m	>8.0m - <15m	>15m
Buildings	Buildings (Vertical)	<1.5m	>1.5m - <4.0m	>4.0m - <8.0m	>8.0m - <15m	>15m
	Buildings (Horizontal)	<1.5m	>1.5m - <4.0m	>4.0m - <8.0m	>8.0m - <15m	>15m
	Building Minimum Size (m^2)	<5m^2	>5m^2 - <15m^2	>15m^2 - <30m^2	>30m^2 - <50m^2	>50m^2
	Absorption coefficient	No error	Use absorption classes	Use absorption classes	No info (reflective)	No info (reflective)
Barriers	Barriers (Vertical re road surface)	<0.5m	>0.5m - <1.0m	>1.0m - <2.0m	>2.0m - <5.0m	>5.0m
	Barriers (Horizontal, re road surface)	<1.5m	>1.5m - <4.0m	>4.0m - <8.0m	>8.0m - <15m	>15m
	Barrier Minimum Height (m)	<1.0m	>0.5m - <1.0m	>1.0m - <2.0m	>2.0m - <5.0m	>5.0m
	Barrier Minimum Length (m)	<10m	>10m - <25m	>25m - <40m	>40m - <100m	>100m
	Absorption coefficient	No error	Use absorption classes	Use absorption classes	No info (reflective)	No info (reflective)
Ground Cover	Hard / Intermediate / Soft ground ratio	<5%	>5% - <10%	>10% - <25%	>25% - <50%	>50%
	Ground Type minimum size (m^2)	<5m^2	>5m^2 - <15m^2	>15m^2 - <30m^2	>30m^2 - <50m^2	>50m^2

Notes:

1. The above uncertainty ranges are based upon the "worst case" identified for each aspect from the single parameter sensitivity test

2. The heavy vehicles speed has become the key factor due to the uncertainty behaviour for Flat roads, the up or down cases give almost double the ranges stated above

3. The "No info" entries have a suggested default value which minimises the potential error

Table 4.3 shows that in the case of multiple input uncertainties, the recommendations for the uncertainty values to be used in order to assess the quality of an input dataset for noise mapping purposes are higher than the case of single input uncertainty.

Table 4-3: Level of accuracy required of the vehicle velocity and traffic flow for decibel errors of 1 and 5 dB(A) in the calculated result for different road gradients. Pulsed decelerated traffic flow model.

	High Noise Case			Low Noise Case		
	Up	Down	Flat	Up	Down	Flat
Hq, Lq, Hv, Lv ±1dB(A) error	±10%	±20%	±10%	±10%	±10%	±10%
Hq, Lq, Hv, Lv ±5dB(A) error	±80%	±90%	±50%	±90%	±70%	±60%

Figure 4-1: A guideline of the level of accuracy recommended for the input parameter for different decibel errors in the strategic noise mapping.

	Key	
Group A		<0.5dB(A)
Group B		0.5-1dB(A)
Group C		1-3dB(A)
Group D		3-5dB(A)
Group E		>5dB(A)

HEPWORTH ACOUSTICS
noise and vibration consultants   20   dGmR   ACUSTINET
Ingeniería en acústica y ruido ambiental

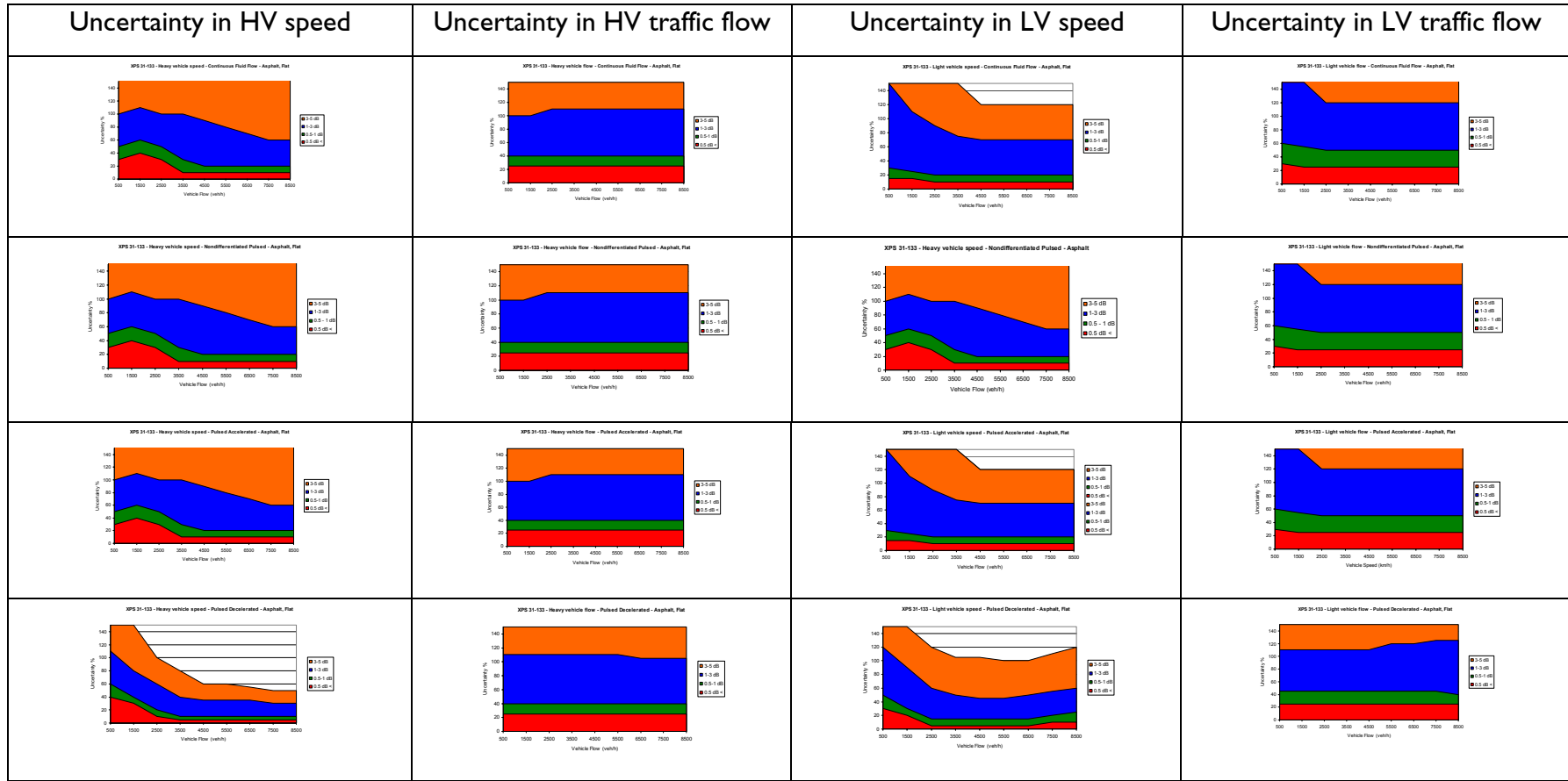| Uncertainty in HV speed	Uncertainty in HV traffic flow	Uncertainty in LV speed	Uncertainty in LV traffic flow

Figure 4-2: A guideline of the level of accuracy required of the input parameter for different decibel errors in the strategic noise mapping. Uncertainty is plotted against vehicle speed.

4.4 Notes on manipulating input data for noise mapping purposes

The input datasets presented at the commencement of a noise mapping project not only need to be analysed in order to determine their quality, but also to enable them to best serve the purpose of noise mapping calculations. Frequently, input datasets are presented at a level of precision which is quite unnecessarily detailed for noise mapping calculations. An example could be the frequency with which points along equal height contours, or road centrelines are specified.

The values above may act as a guide to the extent to which incoming datasets may be simplified, before being passed into the noise calculation software, without this simplification detracting from the overall quality objectives of the project.

In addition to the above guidance, there are further points raised below which it is considered appropriate to consider whilst creating a noise calculation model from received information.

4.4.1 Road Segmentation

Road segmentation is normally handled on an automatic basis by advanced noise software tools as the roads are "draped" onto the underlying ground elevation model. In certain situations it is possible this may not occur, such as when there is no ground elevation model available, or in areas of very level ground. It is therefore recommended that the road centreline dataset is pre-segmented such that even in the absence of sub-segmentation by the software, it complies with the segmentation rules set out within the calculation standard.

In this example we will use CRTN, which states that segmentation should occur in accordance with a 2 dB change rule, i.e. the variation in potential emission level should be restrained to less than a 2 dB change within one segment. On this basis, the road centrelines should be segmented in line with the following rules:

- Max change between segments 2dB
    - Max change in gradient 6%
    - Max gradient 30% limited
    - Horizontal deviation: Centreline deviates from actual centreline by no more than 1.0m horizontally
    - Vertical deviation: lane centreline deviates from actual by no more than 0.5m vertically
    - Change in traffic flow by no more than 10%

- o Change in %HGV by no more than 40%

- o Change in road surface type

- o Change in texture depth by more than 0.4mm

- o Traffic speed changes by no more than 10%, or changes default road type class

- o Road carriageway width changes by no more than 1.0m

- o When road changes from two way to one way

- o Split carriageways should be modelled with two centrelines in the following situations:

  - More than 5.0m separation between lanes

  - More than 1.0m height difference between outside edges of lanes

  - When there are 4 lanes in one or both directions

  - Possibly when there are 3 lanes in one or both directions

4.4.2 Barrier Segmentation

- Barrier segmentation should occur:

  - o When height of top of barrier changes by more than 0.5m (relatively to the road surface)

  - o When horizontal location differs by more than 1.0m horizontally – try to link to road centreline segmentation when they are parallel

NOTE: There is a special case for roadside barriers where they are likely to be the most significant screening effect from a road section. Here the desire is to link the segmentation to that of the roads, as mentioned above. It is also desirable to limit the "relative" vertical and horizontal uncertainties, between the road centreline and the barrier, to values below those shown above. Where the barrier and road centreline locations and height datasets come from independent sources, the potential uncertainty will be increased, and the potential for error greater.

4.4.3 Ground Terrain Modelling

The ground terrain profile will need to be represented using two forms of objects to provide compatibility with the noise mapping software tools, and to help provide a dataset best fit for purpose and optimised for noise calculations.

- Equal Height Contours, see table 8.6.2

- Ground Contour Profiles
  These are lines, or polylines, which vary in height along their length. They are used to define ground model elements such as:

  o Slope edges

  o Embankment top and bottom

  o Earth bund top and bottom

  o Escarpment edges

  o Cuttings

  The vertical accuracy of the points along these lines should follow the recommendation in Table 8.6.2 above.

4.4.4 Building Height Information

Within urban areas where building density is high, the two most important potential noise barriers considered by the calculation method will most likely be the building nearest to the source, and the building nearest to the grid receptor, within the propagation path.

In residential and suburban areas the use of a default building height of 8m, as is common for city noise maps, will lead to only a small potential error in calculated noise levels. However, in city centre locations, or areas with a large percentage of buildings over two storeys high the use of default building heights is likely to introduce significant errors. When using certain existing national calculation methods, which do not provide the option to calculate noise levels on the quiet façade, the use of genuine building heights within areas of high rise development, may lead to calculated noise levels much less accurate than when using an 8m default building height, as they may become unrealistically low.

In rural areas the major screening barriers within the calculation are more likely to be earth embankments or noise barriers, than high rise buildings. In which case the likelihood of error being introduced by using default buildings heights in rural locations, will be lower than in city locations.

For these reasons it is recommended that real building heights are used within city or urban locations, if available, whilst default building heights could be more appropriate for calculations in rural areas.

4.4.5 Data Accuracy Constraints across Data Corridor

Means of assessing the width of the data corridor, or the agglomeration buffer zone are presented in the WG-AEN GPG Toolkit 16. To compliment this existing advice it is considered appropriate to discuss the requirement for data accuracy across the data corridor.

As the potential accuracy of the calculation methods to be used generally decreases with increasing distance from the source, the specified accuracy of model input data should be highest near to the source, and may be acceptable at a lower level further away from the source. The recommended aim is to achieve Group B accuracy within close proximity to the road and rail emission lines, possibly the first 50m either side, with Group C accuracy constraints being acceptable out to 600m, and possibly Group D level accuracy out to longer distances in the buffer areas.

4.4.6 Modelling of Acoustic Ground Type

The default ground type for the dataset should be acoustically hard, with areas of intermediate and soft ground defined as closed polygon. Where possible these polygons should be concatenated to produce a simplified dataset containing a smaller number of large soft ground areas.

4.5 Analysis of noise mapping input data

It is accepted and understood that the input data required for wide area, large scale, noise mapping is not universally available across MS. For this reason there is set out below an indicative process by which the noise mapping data could be selected:

- Scoping study analyses data, and gaps in data
    - o Assess the uncertainty of each input data set
        - ▪ This report offers guidance on some aspects
        - ▪ GPG v2 offers guidance of absolute accuracy of some aspects
    - o Fill in blanks with GPG
        - ▪ GPG v2 to provide absolute accuracy assessment within each Toolkit
        - ▪ The dB implications of the decisions may be understood
    - o Commission data capture exercise
        - ▪ Limited budgets – where will expenditure provide best improvement in results?

- Limited time – which parameter should we investigate

- Limited techniques – should new techniques be developed for key aspects?

4.6 Summary of Recommendations

The focus on controlling the uncertainty in the vertical height of barriers near to the sources is inline with the advice presented above in the sensitivity tests carried out on XPS 31-133.

To summarise the preceding section it can be considered with regard to XPS 31-133:

- Calculated noise levels within the 300m validation range are generally within 1dB of measured levels, given high quality input data, such as that which results from observed monitoring and simultaneous data capture;

- Out to 600m this calculation error is likely to increase to around 3dB;

- The potential error out to 2 – 3km may well be up to 10dB, or possibly more;

- Management of the uncertainty in vertical, Z, attributes on model information is much more important than the exact horizontal location;

- As the potential accuracy of the calculation method decreases with increasing distance from the source, the specified accuracy of model input data should be highest near to the source, and may be acceptable at a lower level further away from the source;

- The default ground type for the dataset should be acoustically hard, with areas of soft ground defined as closed polygon; and

- Due to the compound nature of uncertainty, the total uncertainty of the result will be higher than the uncertainty of the individual input datasets.

5.   Conclusion

This research project has carried out the first significant investigation into input data accuracy requirements in the context of environmental noise mapping. The results of the single parameter and multi-parameter error propagation testing of the XPS 31-133 noise emission model have helped to gain an understanding of the effect upon the receptor decibel result levels calculated due to errors or uncertainties within the input datasets.

The results of the technical investigations have been presented in other reports associated with this research project, and have been interpreted and re-presented in two further sets of practical recommendations. In one of these reports the GPG Toolkits are presented with quantified decibel accuracy statements in order to provide a usable guide relating to EU noise mapping projects.

In this, the second recommendation document, the results are used to help drawing up an interpretation of the END in the context of data requirements, and to presents the results in a series of equal noise error bands to help illustrate the order of merit of the datasets, and the potential for resultant error connected with uncertainty in each. These tables can be used to help in equalising effort across the various input datasets in an effort to maximise value and minimise error. It also needs to be considered that the results of the multi-parameter testing indicated that even if each individual dataset uncertainty was constrained within an error band of say 3 dB, the total resultant uncertainty of the final result is most likely to be in the next uncertainty band above, in this case 5 dB.

Finally, the research has shown that the level of error within the calculated result can be significant in the context of the 5 dB bands of results required for the EU END noise mapping in 2007. The level of accuracy required for some input datasets may well challenge the best information currently available across the EU, and should be seen as an indication towards how data capture and management organisations need to be worked with proactively by the acoustics community if the results in 2012 are to be of a higher degree of accuracy.