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

Research Project NAN R 208: Noise Modelling

Final Report - Part 6: Data Accuracy Guidelines of RMR Interim

Document Code: HAL 4305.3/6/2
DGMR V.2006.1247.00.R4-6

May 2007
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1. Executive Summary

1.1 Project

Defra has let a research project on behalf of the EC Working Group on the Assessment of Exposure to Noise (WG-AEN) to determine the likely effects on the acoustic accuracy of the advice contained within the Working Group’s Position Paper “Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise exposure” Version 2 January 2006 (GPG v2). The key objectives of the project are summarised as follows:

- To extend and build upon the work carried out in the original Research Project NANR 93, “WG-AEN’s Good Practice Guide & the Implications For Acoustic Accuracy”;

- To quantify the accuracy symbols within the GPG v2 when Toolkits 8, 9, 12, 13, 15 and 16 are used in conjunction with the UK Calculation of Railway Noise, 1995, (CRN) and the recommended adapted Interim Method for the assessment of Railway Noise based upon the Netherlands method RMR 1996 (RMR Interim);

- Provide additional practical guidance on any issues concerning the application of the Toolkits 8, 9, 12, 13, 15 and 16 in the GPG v2 relating to railway noise mapping that are uncovered whilst undertaking the study; and

- To provide practical guidance on the consequences of the accuracy of input datasets that are suitable for use with CRN and RMR Interim for noise mapping purposes, through the use of error propagation techniques.

1.2 Data Accuracy Guidelines for RMR Interim

Across the EU Member State the requirements for the END are driving 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 RMR Interim 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.

The non-geometrical Monte Carlo tests have shown that for category 9 vehicles, uncertainty in the train speed produces larger uncertainty in the total train emission than does the same degree of uncertainty in the flow.

It has also shown that for vehicle categories 1 to 8 the magnitude of the speed influences the required input uncertainty for a given level of uncertainty in the results. Over the flow scenarios and speeds assessed as part of this research, the general indication is that for flow scenarios where the noise emission is dominated by low speed vehicles the uncertainty in the speed is more influential than in the flow. For scenarios dominated by noise from high speed vehicles it is generally more important to manage uncertainty in the flow values. For evenly mixed flow scenarios, or predominantly medium speed vehicles the influence of uncertainties in the flow and speed are likely to be similar.

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, reflection properties or ground absorption.

These results have been further utilised to form the basis of the GPGv2 Toolkits with quantified accuracy statements, presented within Final Report – Part 4 of this research.
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5. Conclusions

Appendix A: References
2. Introduction

2.1 Background

WG-AEN was originally set up at the end of 2000 with a two year remit, which included the development of the guidance within a Good Practice Guide (GPG). GPG version 2 was issued as a Final Draft in January 2006. Version 2 of the Position Paper replaces version 1 and states within the Introduction:

“Version 1 has been revised, modified and enhanced to take account of the feedback from the consultation process and recent developments, including the results of a research project sponsored by the United Kingdom (UK) Government (see section 1.6 for further details). Readers of this Version 2, hereinafter referred to as the or this ‘Position Paper’, should note that there are significant changes between this Position Paper and Version 1, for example the way that the issue of assigning noise levels to buildings is dealt with. (This is one of the most important alterations that have resulted from the consultation process.)”

The research project referenced is the original NANR 93 project “WG-AEN’s Good Practice Guide & the Implications For Acoustic Accuracy” carried out by Hepworth Acoustics, DGMR and Acustinet and published in 2005.

The GPG v2 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 v2 are designed to provide guidance of 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.

GPG v2 provides practical advice on decision making in the absence of detailed data, and provides an indication of the acoustic accuracy implications of making the decisions only for Toolkits associated with the assessment of road traffic noise, as a result of the NANR 93 Research Project. Unfortunately this still results in the MS making choices where the uncertainty in results introduced into the process is unknown for railway noise, industrial noise, aircraft noise and weather information; and therefore both the MS and the EU Commission are uncertain about the potential accuracy and robustness of the results, even when the methodology is documented and has followed the advice within the GPG v2. A second consequence, and possibly of equal importance is that this lack of quantified acoustic guidance for railways, industry, aircraft and weather datasets within the GPG v2 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. The discussion of uncertainty in
noise mapping, and the practical guidance on datasets for road traffic noise assessments help to provide a much needed introduction to the issues, but then leave the decision makers with an incomplete set of information to deal with all the challenges facing them.

Defra wish to continue to study the consequential acoustic accuracy in strategic noise map results due to adopting the advice in the present version of the GPG v2, by now focusing on railway noise. The results of this study provide practical advice and guidance on the potential acoustic accuracy implications of following the advice within the GPG v2 Toolkits 8, 9, 12, 13, 15 and 16, and thus help to inform Member States, competent authorities and the EU Commission as to the robustness of the results submitted in 2007 under the END framework.

The guidance should also help to inform 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 which will provide the most benefit to the acoustic accuracy of the results.

2.2 Scope of Research Project

This research project sets out to assess the implications on acoustic accuracy of following the recommended steps within the GPG Toolkits by following the process described in detail within the following sections.

2.2.1 Aims

The Aims of the project are:

- To provide practical guidance on the acoustic accuracy implications of following the recommendations within the toolkits 8, 9, 12, 13, 15 and 16 in the GPG v2, which shall be produced in a manner which is compatible with the contents of the GPG v2; and

- To provide practical guidance on the consequences of the accuracy of input datasets that is suitable for use with CRN and RMR Interim for noise mapping purposes.

2.2.2 Objectives

The main objectives of this research project for Defra are:

- To extend and build upon the work carried out in the original Research Project NANR 93, “WG-AEN’s Good Practice Guide & the Implications For Acoustic Accuracy”;

- To quantify the accuracy symbols within the GPG v2 when Toolkits 8, 9, 12, 13, 15 and 16 are used in conjunction with the Calculation of Railway Noise, 1995,
(CRN) and the recommended Interim Method for Calculating Railway Noise, described within Annex II, 2.2 of the END (RMR Interim);

- Provide additional practical guidance on any issues concerning the application of the Toolkits 8, 9, 12, 13, 15 and 16 in the GPG v2 relating to railway noise mapping that are uncovered whilst undertaking the study; and

- To provide practical guidance on the consequences of the accuracy of input datasets that are suitable for use with CRN and RMR Interim for noise mapping purposes, through the use of error propagation techniques.

2.2.3 Objectives of Research Tasks

The tasks and objectives of the research are:

1. Briefly review the testing methodology used to determine the implications for acoustic accuracy of adopting the advice in the GPG v2 as developed during Stage 1 (NANR 93) of the research, and propose enhancements or amendments to this methodology as required;

2. Carry out quantitative testing of the accuracy symbols using the proposed methodology on the GPG Toolkits mentioned above, when used in conjunction with CRN and RMR Interim;

3. Report on the acoustic implications of using the GPG v2 Toolkits as revealed by the testing methodology;

4. Carry out error propagation testing of CRN and RMR Interim in order to provide guidance on the consequences of the accuracy of input datasets that would be used with these procedures;

5. Liaise throughout with the WG-AEN and Defra (by 4 weekly email updates and up to 2 meetings, involving the WG-AEN) to ensure the project develops in line with their end user requirements; and

6. Provide the following documents in a format suitable for publication both in print form and on the Department’s web site:
   - An initial report of the results of the investigations carried out under task 1;
   - A final report covering tasks 1 to 4; and
   - A final report incorporating comments from Defra and WG-AEN.

These main tasks have been analysed to develop the detailed project approach set out in report 4305-3-1 Project Approach.
3. Assessing the Requirements for Noise Mapping - RMR Interim

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 as well as an outline of aspects to be considered along with the actual dataset design advice. This document ensures that guidance is viewed in its entirety, rather than viewed in isolation from the context to which it applies.

3.1 Background to the Recommendations

The European Commission's 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 CMs is by the development of Noise Action Plans (NAP).

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

The manner in which the results from the noise maps must be described is set out; in 5dB(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, plus major roads, major railways and major airports outside agglomerations.

3.2 RMR Interim for Noise Mapping

Under the requirements of the END a Member State is able to choose either the recommended Interim Methods, or existing national methods, for the assessment of noise.

Annex II 2.2 of Directive 2002/49/EC covers “Assessment Methods for the Noise Indicators” the recommended interim calculation method for railway noise is:


The next paragraph then sets out the following requirement regarding the recommended interim methods:
“No later than 1 July 2003 the Commission will publish guidelines in accordance with Article 13(2) on the revised methods and provide emission data for aircraft noise, road traffic noise and railway noise on the basis of existing data.”

The Official Journal of the European Union (OJEU) 6 August 2003 contained Commission Recommendation “concerning the guidelines on the revised interim computation methods for industrial noise, aircraft noise, road traffic noise and railway noise, and related emission data”, although it should be noted that the notice is headed with the statement “Acts whose publication is not obligatory”.

A summary of the elements relating to the assessment of railway noise is set out below:

<table>
<thead>
<tr>
<th>Section</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FOR RAILWAY NOISE: the Netherlands national computation method published in ‘Reken- en Meetvoorschrift Railverkeerslawaai ’96, Ministerie Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 20 November 1996’. This method is referred to as ‘RMR’ in these guidelines. The above mentioned methods must be adapted to the definitions of L&lt;sub&gt;den&lt;/sub&gt; and L&lt;sub&gt;night&lt;/sub&gt;</td>
</tr>
<tr>
<td>2.1.1</td>
<td>L&lt;sub&gt;DEN&lt;/sub&gt; is derived from L&lt;sub&gt;day&lt;/sub&gt;, L&lt;sub&gt;evening&lt;/sub&gt; and L&lt;sub&gt;night&lt;/sub&gt; using the following formula: $L_{den} = 10 \times \log_{10} \left[ \left( 12 \times 10^{L_{day}/10} + 4 \times 10^{L_{evening}/10} + 8 \times 10^{L_{night}/10} \right) / 24 \right]$</td>
</tr>
<tr>
<td>2.1.2</td>
<td>Receiver height set at 4.0m</td>
</tr>
<tr>
<td>2.1.3</td>
<td>Meteorological correction&lt;br&gt;Where good quality data is available: “Derive average meteorological data from an analysis of detailed meteorological data.”&lt;br&gt;Where such data is not available: “Adopt a simplified assumption for overall meteorological data.”</td>
</tr>
<tr>
<td>2.3.1</td>
<td>Description of Calculation Method&lt;br&gt;SRM I and SRM II from RMR 1996 both acceptable provided the conditions set out within the original text are met.</td>
</tr>
<tr>
<td>2.3.2</td>
<td>Noise Indicator&lt;br&gt;“average train data for the relevant year have to be provided and assessment periods day, evening, night”</td>
</tr>
<tr>
<td></td>
<td>Propagation - meteorology</td>
</tr>
</tbody>
</table>
Use RMR CM (with C0 set to 3.5 dB)

Propagation - atmospheric absorption

Use Table 5.1 of RMR 1996 unless “In some particular situations in some Member States, these coefficients may need to be adapted. This should be done following ISO 9613-1.”

3.2.1 Use emission model set out in Chapter 2 of RMR 1996 without modification.

3.2.2 - Place railway vehicles into 10 categories as per 3.2.2.1, or
- carry out measurements to create additional categories as per 3.2.2.2

3.2.2.1 Lists the 10 categories from RMR, which are primarily differentiated by propulsion system and wheel brake system

3.2.2.2 “The noise emission characteristics of a railway vehicle or of a track can be determined by measurement. The measurement procedures are described in:


Three procedures are given to determine the characteristics of new train categories or non-Dutch rolling stock on non-Dutch tracks (procedures A and B) and of non-Dutch tracks (procedure C)”

3.2.2.3 The SRM I and SRM II emission models are described

Prior to the publication of the OJEU notice, there was issued the final report from EC Contract B4-3040/2001/329750/MAR/C1 “Adaptation and revision of the interim noise computation methods for the purpose of strategic noise mapping” lead by Wölfel Meßsysteme & Software GmbH & Co. It is very important to note that the Final Report from the Wölfel project does not contain the same recommended adaptations as the OJEU notice 2003/613/EC.

The final report does, however, provide the only accessible version of RMR 1996 for non-Dutch speakers, via the edited non-contextual translation into English, see WP 3.2.1 of the Wölfel research project EC Contract B4-3040/2001/329750/MAR/C1. Unfortunately the project team are not aware of a complete, unedited, translation of RMR 1996 which may be recommended to Member States.

The technical specification for the railway noise calculation method investigated within this research project is described as:

• Plus the Commission Recommended Adaptation from 2003/613/EC.
  o Note: Where English speaking members of the project team had a query regarding the exact meaning of a phrase within the Wölfel non-contextual translation of the method, the native Dutch speaking team members from DGMR and DeltaRail advised upon correct interpretation.

This method is referred to throughout this project report as “RMR Interim” in an attempt to distinguish it from the original RMR 1996, or the more recent draft versions from RMVR 2002 and RMVR 2004 or the published RMR 2006.

A full discussion on the RMR Interim assessment method is set out in Final Report – Part 2, Section 3.

3.3 Sources of Uncertainty in Noise Mapping

Isukapalli and Georgopoulos¹ 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.

It is noted that the current project is only investigating uncertainty propagation through the RMR Interim calculation method, via two different sets of step changes, (1) in line with the GPG v2 Toolkit steps, both individually and in combination; and (2) as individual input parameter variations across the range of probable input values, both for individual parameters, and in combination.

Figure 3.1 gives a graphical representation of how the different sources of uncertainty interact.

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

Figure 3.1: Sources of uncertainty in noise modelling

3.3.1 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 except for cases where actual information was available on the distribution of measured values.

3.3.2 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 in Final Report - Part 4 for the Toolkits 8, 9, 11, 12, 13, 14, 15 and 16 in the GPG v2 refer to the RMR Interim Method for the calculation of railway noise.

Some results specific to the use of the RMR Interim 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 for the END maps if such information is not currently available.

3.3.3 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 tool’s 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.

3.3.4 Uncertainty of Evaluation Data
The issues surrounding uncertainties in environmental noise measurements have been researched in detail by Craven & Kerry\(^2\) whose work suggested that for short term measurements you were doing well if repeat measurements are within 5dB(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.

Work within the Harmonoise/Imagine projects has carried out long term monitoring exercises and compared them with calculations using the Harmonoise/Imagine 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.

3.4 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 tried 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”

  o “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 RMR 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 1dB error;

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

- Group D is aimed to manage the input specifications such that potential errors in each aspect produce less than 5dB of error. **NOTE:** in some cases, for END mapping, use of the guidance within the GPG v2 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 be a combined error of higher magnitude. For example, managing to contain each input dataset to fit within Group C, less than 2dB per parameter variation, could lead to an overall calculated level with an uncertainty in the order of 5dB.
4. Recommendations for input dataset requirements

This section presents the recommendations based upon the results of the error propagation analysis carried out within this research project for RMR Interim. Recommendations on accuracy for input data requirements are made for both the geometrical and non-geometrical aspects of the RMR Interim method.

4.1 Non-Geometric Aspects

4.1.1 Parametric Input Data

Train Flow & Speed

- For category 9 vehicles uncertainty in the train speed produces larger uncertainty in the total train emission than does the same degree of uncertainty in the flow. It is recommended that the train speeds for this vehicle category are captured to within an uncertainty of 10% in order to maintain a good level of accuracy (less than 1dB) in the total train emission. For the same 1 dB constraint the vehicle flow value should be within an uncertainty of 18%;

- For vehicle categories 1 to 8 the magnitude of the speed influences the required input uncertainty for a given level of uncertainty in the results. Over the flow scenarios and speeds assessed as part of this research, the general indication is that for flow scenarios where the noise emission is dominated by low speed vehicles the uncertainty in the speed is more influential than in the flow. For scenarios dominated by noise from high speed vehicles it is generally more important to manage uncertainty in the flow values. For evenly mixed flow scenarios, or predominantly medium speed vehicles the influence of uncertainties in the flow and speed are likely to be similar;

  o For vehicles in categories 1 to 8 it is recommended that the train flows are captured to within an uncertainty of 18% in order to maintain a good level of accuracy (less than 1dB) in the total train emission, independent of vehicle speed;

  o For vehicles in categories 1 to 8 it is recommended that the train speeds are captured to within an uncertainty of 5 to 22% in order to maintain a good level of accuracy (less than 1dB) in the total train emission. The magnitude of the decibel uncertainty in the total emission level rises as the speed of the dominant emission vehicles falls, thus for flow scenarios dominated by noise from high speed vehicles 1 dB resultant uncertainty will be towards the top end of the range, whilst for flow scenarios dominated
4.1.2 Non-Parametric Input Data

**Train Vehicles**

- The train category testing investigated the decibel uncertainty in the total emission level due to uncertainty in allocating rail vehicles from generalised descriptions into the vehicle categories presented in RMR Interim. Two methods of assigning trains from descriptions to the RMR Interim categories were tested, with an assumption that flows from each description should be distributed evenly across potential train categories. The two methods relate to an individual's ability to capture, identify and relate different train vehicles to the 9 categories in RMR Interim. The more detailed method was labelled the 'train spotter capture', whereas the less accurate method was labelled the 'technician' capture.

- Correct identification of train categories within RMR Interim is an important process, not only because of the need to identify the appropriate emission terms for the vehicles, but also because there are secondary dependencies related to the vehicle category. As discussed above the speed correction factor for each vehicle category is different, as is the effect of vehicle braking, the track correction factors, and in the case of Category 9 the emission heights change. In order to help reduce these secondary uncertainties it is considered important to either correctly identify vehicle categories, or where this is not possible, evenly spread vehicles across categories of similar type so as to try and minimise the uncertainty introduced.

- In the study, for train spotter capture, rail vehicles have been allocated into 5 categories generalised from the 9 vehicle categories in RMR Interim and for the technician capture, rail vehicles have been allocated into 4 generalised categories.

- The results of the study show small differences between dB uncertainties introduced in the total emission level between the train spotter and technician captures. Both captures have an associated uncertainty of around 1 dB. In a situation where the capture has resulted in the dominant vehicle categories changing to other noisier vehicle categories, or the spread over many other categories, the resultant dB uncertainty can be as high as 2.5 dB. In this situation, the ability to identify trains more accurately (train spotter capture than technician capture) can reduce the resultant uncertainty.

- In the absence of being able to assign trains directly into a single RMR Interim category, the distribution of vehicles evenly across similar RMR Interim vehicle categories is recommended, as this has been shown to introduce uncertainties of up to 2.5 dB, and typically in the order of 1 dB.

**Note:** It should be noted that this testing has not considered the likely situation when non-Dutch vehicles have noise emissions somewhat different from Dutch vehicles with
a similar technical description. There are many factors, including wheel/rail roughness, which may influence the emissions from rail vehicles across the EU which were outside the scope of this research.

**Track Type and Construction**

- Where no knowledge of actual track type is known, the testing shows that the maximal potential error of assigning default track types to sources is locally up to 7 dB. If a default track type is to be applied because of a lack of track type data, track type 2.1 (joint-less rails on wooden or zigzag concrete sleepers in ballast) will yield the smallest uncertainty in noise levels.

- In order to avoid errors of more than 1 dB in the calculated noise levels, a 7 dB track type error should be existent within no more than 12 decimal degrees (0.2 radians) viewing angle of receivers. With a minimum receiver distance of 20m, this corresponds with a resolution of 5m track length, at which track type data needs to be captured. Therefore, in order to maintain a good level of accuracy (less than 1dB uncertainty) in the total track emission it is recommended that the track types are captured without errors at a resolution of 5m track length.

- Testing also investigated the case where the dominant track type is known within a noise mapping area, or sub-area, and assigned to the whole model. In a situation where this does not correctly identify all of the track types across the model the noise level uncertainty could be up to 4 dB, with a slight increase of the average noise levels.

- These results indicate that if no information is known on track type, then type 2.1 should be assigned. However, the results also suggest that effort expended in correctly identifying the dominant track type within an area will reduce the uncertainty, whilst the additional effort of correctly identifying track types will further reduce uncertainty, and potentially reduce the assessed noise level impact.

**4.1.3 Multiple input parameters**

- The total emission level uncertainty due to multiple simultaneous input uncertainties is larger than those in the single parameter case. This means that in cases where there is more than one input uncertainty, the accuracy requirement for each input parameter will be higher than those of single input uncertainty for a given level of uncertainty in the result. This becomes more significant as the uncertainty level increases and the more GPGv2 toolkits are applied.
4.2 Geometric Aspects

4.2.1 Source height
Due to the fact that the most influential railway sources are low, the sensitivity of the ground effect for source height variations is strong. Secondly, source height variations lead to varying diffraction effects by screening objects. Without the presence of barriers, shallow cuttings and low embankments may lead to limited noise level uncertainty. If the cuttings are possibly deeper, or if embankments are higher than about 1m, or if barriers are potentially situated along the railway, the noise level uncertainty increases rapidly above an acceptable level.

Absolute definition of the source height provides more accurate noise levels than projecting the sources onto a ground model consisting of equal height contours. In addition, the inclusion of accurately defined slope edges to define the terrain in the vicinity of the source is also desirable. These modelling objects in most cases are used in order to support specific attenuations from manmade terrain features. In cases with substantial height differences and a 5m vertical separation between the equal height contours, the noise level uncertainty can possibly reach 8 dB.

4.2.2 Ground surface type
Using hard ground as a default ground type can lead to local inaccuracies of more than 5 dB. For suburban cases with mixed ground, the 95% confidence interval is in the order of 4 dB.

The accuracy of calculations can strongly be improved by distinguishing between urban, suburban and rural areas by the use of polygons with a land use classification, such as the EU wide CORINE dataset. Though extreme local uncertainties may occur as in the case of hard ground by default, 95% of all noise levels will be within +/-3 dB(A).

It is therefore recommended that the use of default ground types should be avoided if possible, and efforts are made to identify the location of ground surface types within the model.

4.2.3 Ground elevation
In hilly terrain, ground elevation variations may lead to diffraction effects and substantial inaccuracies in the ground elevation model. This will have a knock on effect and then lead to extreme associated uncertainties in calculated noise levels. If the ground elevation variations are modelled with an accuracy of 1m, the associated noise levels will approximately be within 2 dB from the crisp values.

Testing has shown that ground elevation accuracy may not be as important as obtaining highly defined ground elevation objects in situations such as cuttings and embankments. This is especially the case where distinct changes in ground elevation occur. It should also be noted that in hilly terrain, an effort must be made to obtain accurate and clearly defined ground elevation data.
The testing also demonstrated that the projecting the railway lines onto a ground model consisting of equal height contours can cause uncertainties in height which produce large uncertainties in the calculated noise levels. In cases with substantial height differences and a 5m vertical separation between adjacent equal height contours, the noise level uncertainty can easily exceed 5 dB.

For this reason it is recommended that the railway corridor is modelled “cut” into the generalised equal height contour ground terrain. The modelling approach recommended is:

1. Introduction of slope edges, running parallel to the sources and with varying height along their lengths to define a rail “corridor” with the railway source line between the inner slope edges defined with slowly changing heights; or where this is not possible

Using equal height contours with small vertical spacing (e.g. 1m).

4.2.4 Barrier height
The effects of inaccuracies in the barrier height generally have a local impact on the noise levels. Although significant uncertainties are found within close proximity to noise barriers, the overall noise levels are generally within 4 dB when the barrier height can be estimated within 1m. The tools investigated in this study have been shown to have both a positive and negative effect on noise levels in the near vicinity of barriers. In the case of barriers running alongside the railway, these effects are typically well within the acoustically relevant footprint (>45 dB),

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 dB.

The classification of buildings by their building type, in order to assign building heights to sub-areas in noise maps, requires a sufficiently accurate spatial definition of these sub-areas. If such areas are defined with sufficient resolution, the noise level uncertainty of the noise map can be reduced to 1.5 dB.

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. When a good estimation of the average height can be assumed, the noise level uncertainty of the noise map is about 2.5 dB.

However, it should be noted that both options in tool15.2 show the potential to produce large statistical uncertainties for some model/flow scenarios, or when the assumptions made do not provide an accurate description of the actual situation. In such cases it is recommended that an accuracy rating of >5 dB is applied to tool 15.2,
but it is also recommended that despite having the same accuracy symbol, the use of building classifications should be considered before adopting default building heights due to the potential for lower uncertainty.

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 buildings or other screening objects, where noise levels are relatively low and the contribution from reflected propagation paths can potentially be significant.

The variation in absorption coefficient between the values 0 and 0.6, suggested in the GPG v2, lead to a maximum uncertainty in noise levels of 2 dB.
4.3 Guidelines

Table 4.1 presents a general guideline of the accuracy range of the input parameters for different decibel uncertainty groups in the total train emission based on the results of the analysis. It is important to realise that the stated accuracy requirements are calculated independently. A certain accuracy level for one parameter is only valid if the other parameters are 100% accurate. A graphical representation of the guideline for train speed is presented in Figure 4.1.

**Table 4.1:** Accuracy of the input parameter required for different uncertainty groups in the train emissions.

<table>
<thead>
<tr>
<th>Source height</th>
<th>Group A &lt;0.5dB(A)</th>
<th>Group B 0.5-1 dB(A)</th>
<th>Group C 1-2 dB(A)</th>
<th>Group D 2-5 dB(A)</th>
<th>Group E &gt;5dB(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 m²</td>
<td>(5-11)%&lt;</td>
<td>(5-11)-(10-22)%</td>
<td>(10-22)-(20-42)%</td>
<td>(20-42)-(50-98)%</td>
<td>&gt;(50-98)%</td>
</tr>
<tr>
<td>0.5 m²</td>
<td>(5-11)%&lt;</td>
<td>(5-11)-(10-22)%</td>
<td>(10-22)-(20-42)%</td>
<td>(20-42)-(50-98)%</td>
<td>&gt;(50-98)%</td>
</tr>
<tr>
<td>2.0 m²</td>
<td>5%&lt;</td>
<td>5-9%</td>
<td>9-18%</td>
<td>18-43%</td>
<td>&gt;43%</td>
</tr>
<tr>
<td>4.0 m²</td>
<td>5%&lt;</td>
<td>5-10%</td>
<td>10-19%</td>
<td>19-46%</td>
<td>&gt;46%</td>
</tr>
<tr>
<td>5.0 m²</td>
<td>4%&lt;</td>
<td>4-8%</td>
<td>8-16%</td>
<td>16-39%</td>
<td>&gt;39%</td>
</tr>
</tbody>
</table>

**Train Speed (V)**

<table>
<thead>
<tr>
<th>Source height</th>
<th>Group A &lt;0.5dB(A)</th>
<th>Group B 0.5-1 dB(A)</th>
<th>Group C 1-2 dB(A)</th>
<th>Group D 2-5 dB(A)</th>
<th>Group E &gt;5dB(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 m</td>
<td>10%&lt;</td>
<td>10-18%</td>
<td>18-35%</td>
<td>35-78%</td>
<td>&gt;78%</td>
</tr>
<tr>
<td>0.5 m</td>
<td>10%&lt;</td>
<td>10-18%</td>
<td>18-35%</td>
<td>35-78%</td>
<td>&gt;78%</td>
</tr>
<tr>
<td>2.0 m</td>
<td>10%&lt;</td>
<td>10-18%</td>
<td>18-35%</td>
<td>35-78%</td>
<td>&gt;78%</td>
</tr>
<tr>
<td>4.0 m</td>
<td>10%&lt;</td>
<td>10-18%</td>
<td>18-35%</td>
<td>35-78%</td>
<td>&gt;78%</td>
</tr>
<tr>
<td>5.0 m</td>
<td>10%&lt;</td>
<td>10-18%</td>
<td>18-35%</td>
<td>35-78%</td>
<td>&gt;78%</td>
</tr>
</tbody>
</table>

**Train Flow (Q)**

Note 1: Apply to train category 9 only.

Note 2: For a given Group, low values of speed have accuracy requirements towards the lower end of the range presented, and high values of speed may have uncertainties towards the upper end of the range presented.
**Figure 4.1:** Accuracy range of the train speed required for different uncertainty groups in the train emission. Source heights 0 and 0.5 metres above the railhead.

**Note:** For a given Group, low values of speed have accuracy requirements towards the lower end of the range presented, and high values of speed may have uncertainties towards the upper end of the range presented.

**Table 4.2:** Accuracy range of the input parameter for different uncertainty groups in the train emission in the case of simultaneous uncertainties in the input parameters.

<table>
<thead>
<tr>
<th>Source height</th>
<th>Group A &lt;0.5dB(A)</th>
<th>Group B 0.5-1 dB(A)</th>
<th>Group C 1-2 dB(A)</th>
<th>Group D 2-5 dB(A)</th>
<th>Group E &gt;5dB(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 m²</td>
<td>(4-8)%&lt;</td>
<td>(4-8)- (9-15)%</td>
<td>(9-15)- (18-28)%</td>
<td>(18-28)- (44-63)%</td>
<td>&gt; (44-63)%</td>
</tr>
<tr>
<td>0.5 m²</td>
<td>(4-8)%&lt;</td>
<td>(4-8)- (9-15)%</td>
<td>(9-15)- (18-28)%</td>
<td>(18-28)- (44-63)%</td>
<td>&gt; (44-63)%</td>
</tr>
<tr>
<td>2.0 m²</td>
<td>4%&lt;</td>
<td>4-9%</td>
<td>9-17%</td>
<td>17-41%</td>
<td>&gt; 41%</td>
</tr>
<tr>
<td>4.0 m²</td>
<td>5%&lt;</td>
<td>5-9%</td>
<td>9-18%</td>
<td>18-44%</td>
<td>&gt; 44%</td>
</tr>
<tr>
<td>5.0 m²</td>
<td>4%&lt;</td>
<td>4-8%</td>
<td>8-15%</td>
<td>15-37%</td>
<td>&gt; 37%</td>
</tr>
</tbody>
</table>

**Note 1:** Apply to train category 9 only.

**Note 2:** For a given Group, low values of speed have accuracy requirements towards the lower end of the range presented, and high values of speed may have uncertainties towards the upper end of the range presented.
Table 4.2 presents the accuracy range of the input parameters for different error groups in the total emission level in the case of simultaneous uncertainties in the input parameters. It is important to realise that the stated accuracy requirements are calculated independently. A graphical representation of the guidelines is presented in Figure 4.2.

![Figure 4.2](image)

**Figure 4.2**: Accuracy range of the input parameter for different error groups in the total train emission in the case of simultaneous uncertainties in the input parameters at source heights 0 and 0.5 metres above the railhead.

Table 4.3, 4.4 and 4.5 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.

**Table 4.3**: RMR Interim Railway source geometry

<table>
<thead>
<tr>
<th>Factor</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>Group D</th>
<th>Group E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>No info</td>
<td>No error</td>
<td>No error</td>
<td>No error</td>
<td>No info</td>
</tr>
<tr>
<td>Rail Type (default type)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Railway centreline (Vertical)</td>
<td>&lt;0.5m</td>
<td>&gt;0.5m - &lt;1.0m</td>
<td>&gt;1.0m - &lt;2.0m</td>
<td>&gt;2.0m - &lt;5.0m</td>
<td>&gt;5.0m</td>
</tr>
<tr>
<td>Railway centreline (Horizontal)</td>
<td>&lt;1.5m</td>
<td>&gt;1.5m - &lt;4.0m</td>
<td>&gt;4.0m - &lt;8.0m</td>
<td>&gt;8.0m - &lt;15m</td>
<td>&gt;15m</td>
</tr>
<tr>
<td>Factor</td>
<td>Group A</td>
<td>Group B</td>
<td>Group C</td>
<td>Group D</td>
<td>Group E</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Ground Model</td>
<td>Ground height, contours, TINs etc (Vertical)</td>
<td>&lt;0.5m - &lt;1.2m</td>
<td>&gt;1.2m - &lt;2.5m</td>
<td>&gt;2.5m - &lt;5.0m</td>
<td>&gt;5.0m</td>
</tr>
<tr>
<td></td>
<td>Ground height, contours, TINs etc (Horizontal)</td>
<td>&lt;1.5m - &lt;4.0m</td>
<td>&gt;4.0m - &lt;8.0m</td>
<td>&gt;8.0m - &lt;15m</td>
<td>&gt;15m</td>
</tr>
<tr>
<td></td>
<td>Profile edges (Vertical)</td>
<td>&lt;0.5m - &lt;1.2m</td>
<td>&gt;1.2m - &lt;2.5m</td>
<td>&gt;2.5m - &lt;5.0m</td>
<td>&gt;5.0m</td>
</tr>
<tr>
<td></td>
<td>Profile edges (Horizontal)</td>
<td>&lt;1.5m - &lt;4.0m</td>
<td>&gt;4.0m - &lt;8.0m</td>
<td>&gt;8.0m - &lt;15m</td>
<td>&gt;15m</td>
</tr>
<tr>
<td></td>
<td>Equal height contour spacing (Vertical)</td>
<td>&lt;0.5m - &lt;1.0m</td>
<td>&gt;1.0m - &lt;3.0m</td>
<td>&gt;3.0m - &lt;10m</td>
<td>&gt;10m</td>
</tr>
<tr>
<td>Buildings</td>
<td>Buildings (Vertical)</td>
<td>&lt;1.5m - &lt;4.0m</td>
<td>&gt;4.0m - &lt;8.0m</td>
<td>&gt;8.0m - &lt;15m</td>
<td>&gt;15m</td>
</tr>
<tr>
<td></td>
<td>Buildings (Horizontal)</td>
<td>&lt;1.5m - &lt;4.0m</td>
<td>&gt;4.0m - &lt;8.0m</td>
<td>&gt;8.0m - &lt;15m</td>
<td>&gt;15m</td>
</tr>
<tr>
<td></td>
<td>Building Minimum Size (m²)</td>
<td>&lt;5m² - &lt;15m²</td>
<td>&gt;15m² - &lt;30m²</td>
<td>&gt;30m² - &lt;50m²</td>
<td>&gt;50m²</td>
</tr>
<tr>
<td>Absorption coefficient</td>
<td>Use absorption classes</td>
<td>Use absorption classes</td>
<td>Use absorption classes</td>
<td>N o info (reflective)</td>
<td>N o info (reflective)</td>
</tr>
<tr>
<td>Barriers</td>
<td>Barriers (Vertical re road surface)</td>
<td>&lt;0.5m</td>
<td>&lt;0.5m</td>
<td>&gt;0.5m - &lt;1.0m</td>
<td>&gt;1.0m - &lt;2.0m</td>
</tr>
<tr>
<td></td>
<td>Barriers (Horizontal, re road surface)</td>
<td>&lt;1.5m - &lt;4.0m</td>
<td>&gt;4.0m - &lt;8.0m</td>
<td>&gt;8.0m - &lt;15m</td>
<td>&gt;15m</td>
</tr>
<tr>
<td></td>
<td>Barrier Minimum Height (m)</td>
<td>&lt;1.0m</td>
<td>&lt;0.5m</td>
<td>&gt;0.5m - &lt;1.0m</td>
<td>&gt;1.0m - &lt;2.0m</td>
</tr>
<tr>
<td></td>
<td>Barrier Minimum Length (m)</td>
<td>&lt;10m</td>
<td>&gt;10m - &lt;25m</td>
<td>&gt;25m - &lt;40m</td>
<td>&gt;40m - &lt;100m</td>
</tr>
<tr>
<td>Absorption coefficient</td>
<td>Use absorption classes</td>
<td>Use absorption classes</td>
<td>Use absorption classes</td>
<td>N o info (reflective)</td>
<td>N o info (reflective)</td>
</tr>
<tr>
<td>Ground Cover</td>
<td>Hard / Intermediate / Soft ground ratio</td>
<td>&lt;5%</td>
<td>&gt;5% - &lt;10%</td>
<td>&gt;10% - &lt;25%</td>
<td>&gt;25% - &lt;50%</td>
</tr>
<tr>
<td></td>
<td>Ground Type minimum size (m²)</td>
<td>&lt;5m² - &lt;15m²</td>
<td>&gt;15m² - &lt;30m²</td>
<td>&gt;30m² - &lt;50m²</td>
<td>&gt;50m²</td>
</tr>
</tbody>
</table>
### Table 4.5: RMR Interim Railway Traffic Data Attributes

<table>
<thead>
<tr>
<th>Factor</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>Group D</th>
<th>Group E</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Source</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train type classification</td>
<td>No error; use measured Lw outside N L</td>
<td>No error; use most similar type outside N L</td>
<td>No error; use most similar type outside N L</td>
<td>No info (choose single average class)</td>
<td>No info (choose single average class)</td>
</tr>
<tr>
<td>Train Speed</td>
<td>(5-11)%&lt;</td>
<td>(5-11)-&lt; (10-22)%</td>
<td>(10-22)-&lt; (20-42)%</td>
<td>(20-42)-&lt; (50-98)%</td>
<td>&gt; (50-98)%</td>
</tr>
<tr>
<td>Train Flow</td>
<td>10%&lt;</td>
<td>10-18%</td>
<td>18-35%</td>
<td>35-78%</td>
<td>&gt; 78%</td>
</tr>
<tr>
<td>Flow Type (braking gear activated)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No error</td>
</tr>
</tbody>
</table>
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 of this could be the frequency with which points along equal height contours, or rail centrelines are specified.

The values above in section 4.3 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 Source Segmentation

Railway source segmentation is normally handled on an automatic basis by advanced noise software tools as the railways 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 even ground. It is therefore recommended that the rail 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 CRN, 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 railway centrelines should be segmented in line with the following rules:

- Max change between segments 2dB
  - Horizontal deviation: Centreline deviates from actual centreline by more than 1.0m horizontally;
  - Vertical deviation: modelled track deviates from actual by more than 0.5m vertically;
  - Change in flow by more than 35%;
  - Change in speed by more than 22% for low speeds, and 42% for high speeds;
  - Change in vehicle braking;
  - Railway embankment width changes by more than 1.0m
4.4.2 Barrier Segmentation

- Barrier segmentation should occur:
  - When height of top of barrier changes by more than 0.5m (relatively to the railhead)
  - When horizontal location differs by more than 1.0m horizontally – try to link to rail centreline segmentation when they are parallel

**NOTE:** There is a special case for railway side barriers where they are likely to be the most significant screening effect from a railway section. Here the desire is to link the segmentation to that of the railways, as mentioned above. It is also desirable to limit the “relative” vertical and horizontal uncertainties, between the rail centreline and the barrier, to values below those shown in Tables 4.3 and 4.4. Where the barrier and rail track centreline locations and heights datasets come from independent sources, the potential uncertainty will be increased, and the potential for error will be 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 Contour (refer to Table 4.4)
- 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:
    - Slope edges
    - Embankment top and bottom
Earth bund top and bottom
- Escarpment edges
- Cuttings

The vertical accuracy of the points along these lines should follow the recommendation in Table 4.4.

### 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 often 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 uncertainty 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 some significant uncertainties. The finding of this research indicates that uncertainties of 9dB are possible within urban areas.

In the tests with lower densities of buildings, such as more rural areas, the effect of building heights remained relevant and the use of default building heights cannot be recommended for railway noise mapping.

### 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 complement 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 soft ground defined as closed polygon or raster. However, there may be locations such as in rural areas where the reverse is considered more appropriate. Where possible these polygons should be concatenated to produce a simplified dataset containing a smaller number of large soft ground areas by smoothing or aggregation. Such processes do however have the potential to reduce the accuracy of the noise
calculation. In some noise modelling packages, it is required that cuttings are modelled within inclusive reflecting ground objects in order to consider cutting correction. This however can be avoided by adopting default hard ground.

It should be noted that RMR Interim method requires that the ground beneath railway sources on ballast is modelled as absorbing ground, the soft ground areas dataset should therefore always include the railway ballast of the considered tracks.

4.4.7 General Discussion Noise Models for Railways

The test results from the RMR Interim research show that accurate height data is much more important in managing the uncertainty in the results than in previous XPS 31-133 Interim noise mapping. This aspect was reviewed at length during the project, and the reason behind it appears to be the fact that within agglomerations, the multitude of minor roads produces noise levels in excess of 45 dB across the whole model, and ensures that almost all receptor points have some unscreened contribution from a road, even if they are minor local roads.

In contrast even within agglomerations the railway noise mapping is more analogous to the major routes between agglomerations, in that there are a small number of noise sources within the model, and the majority of grid receptor points to be assessed will be exposed to little unscreened propagation, and generally be screened by earthworks around the rail corridor, or noise barriers, or the first row of buildings alongside the railway corridor.

For this reason the effect of uncertainty within barrier heights, embankments and cuttings and building heights, is much more marked than for the XPS 31-133 Interim method research within NANR 93.

For these reasons the geometrical requirements for RMR Interim modelling set out in Tables 4.3 and 4.4 are rather more onerous than for XPS 31-133 Interim, which was derived from equivalent model testing, in predominantly urban agglomeration type models.
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 MSs. For this reason the following sets out an indicative process by which the noise mapping data could be selected or collected:

- Scoping study analyses data and gaps in data
  - 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
    - Possibly carry out sensitivity testing
  - Fill in blanks with GPG
    - GPG v2 to provide absolute accuracy assessment within each Toolkit
    - The dB implications of the decisions may be understood
  - 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

To summarise the preceding section it can be considered with regard to RMR Interim:

- Train flows should be kept within 18% in order to maintain a 1 dB uncertainty in the results;

- Train speeds should be kept within 10% (vehicle category 9) and 5-22% (depend upon vehicle categories 1-8) in order to maintain a 1 dB uncertainty in the results;

- Where train vehicle speeds are low the uncertainty needs to be lower than when vehicle speeds are high, for the same level of resultant decibel uncertainty;

- Vehicle information should be accurately obtained for RMR Interim train categories. If this is not possible, the category distribution methods discussed in Final Report - Part 2 should be adopted, however this can introduce uncertainties of up to 2.5 dB, with an average of around 1 dB.

**Note:** It should be noted that this testing has not considered the likely situation when non-Dutch vehicles have noise emissions somewhat different from Dutch vehicles with a similar technical description. There are many factors, including wheel/rail roughness, which may influence the emissions from rail vehicles across the EU which were outside the scope of this research.

- Use of a default track type without knowledge of the actual situation is discouraged, with accurate assignment of changes in track type down to 50m lengths being encouraged. Even the use of a correct dominant track type over the whole map may introduce uncertainties of around 4 dB;

- Calculated noise levels within 300m are generally within 1 dB of measured levels, given high quality input data, such as that which results from observed monitoring and simultaneous data capture or use of the Dutch National Railway Database (ASWIN);

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

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

- Management of the uncertainty in the vertical domain in noise modelling 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 as a result, it may be acceptable to include a lower level of detail and accuracy further away from the source;
• Detailed ground type information may not be available, however it is still recommended that some form of categorised ground cover dataset offers a preferred solution to use of a global default ground surface type; EU wide CORINE data may be considered one such option;

• The default ground type for the dataset should be acoustically hard, with areas of soft ground defined as closed polygon and distinction of the railway ballast as an absorbing surface; 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. Conclusions

This research project set out to quantify the accuracy symbols within several of the GPG v2 Toolkits associated with the assessment of railway noise, and to develop practical guidance for Member States on the implications for calculated decibel levels of using the Toolkit recommendations.

This Final Report sets out the results and recommendations of error propagation testing of six WG-AEN GPG v2 Toolkits when used with the RMR Interim assessment methodology.

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 v2 Toolkits are presented with quantified decibel accuracy statements in order to provide a usable guide relating to EU noise mapping projects.

In this document, the results are used to help draw up an interpretation of the END in the context of data requirements, and to present 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 for example of 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, as with the investigation into road traffic noise modelling, the research has shown that the level of uncertainty within the calculated results can be significant in the context of the 5 dB bands of results required for the EU END noise mapping in 2007. The quality requirement for some of the required 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 lower degree of uncertainty.
Appendix A: References


3 Calculation of Railway Noise 1995 - Department of Transport