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Good practice in the use of noise mapping software

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ABSTRACT

After over 20 years of development, noise mapping software is, today, a professional tool that is widely used by many people with different backgrounds and experience in the applications, the data and the software used. The user has the possibility to influence the quality of the result of the noise mapping process. The major factors affecting good practice include:

- the user's knowledge of the standard
- the user's knowledge of the software
- documentation of software functions and its implementation of the standard
- quality assurance of software implementation
- documentation of software settings in calculation results
- the user's analysis of the quality and impact of the input data

Several methods are available to ensure good practice and improve the quality of output through such methods as standardisation and documentation, training and user certification. For example, in 2006, the European Commission Working Group Assessment of Exposure to Noise produced the "Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure" Version 2.

This paper will describe the major factors where user influences the quality of the results and the methods to ensure good practice and improving the quality of output.

1. INTRODUCTION

The European Directive 2002/49/EC relating to the assessment and management of environmental noise [1] has resulted in pan-European experience of strategic noise mapping with a range of previous user experience and data sets. This year, a 2 day workshop organised by the European Commission and the European Environment Agency on target quality and input values requirements for noise mapping was held [2]. EU Member States' noise representatives, public authorities, private noise consultants and software developers discussed the development of requirements on the input values and their associated quality in view of the next round of European noise mapping. One of the recommendations from the workshop was to maximise the reliability and comparability of results through setting up guidance on the competent use of noise assessment methods accompanied by a quality system covering:

- The relevant quality and quantity of input data
- Guidance on how to use, extract, extrapolate and manage input data
- Software calculation settings
- Software use and modelling
- The mandatory use of the European Commission's reporting mechanism

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Based on their long-term experience in noise mapping software and previous papers (e.g. [3, 4]), the authors have been requested by the Euronoise conference organizers to draft a discussion document on good practice in the use of noise mapping software. This paper describes the major factors where user influences the quality of the results through the use of software and the methods to ensure good practice and improving the quality of output. The authors have organized the major factors affecting good practice as follows:

- the user's knowledge of the standard
- the clearness of the documentation of the standard
- the user's knowledge of the software
- documentation of software functions and its implementation of the standard
- quality assurance of software implementation
- documentation of software settings in calculation results
- the user's analysis of the quality and impact of the input data

As it can be seen above, method developers, software developers and the user share the responsibility for result quality and must follow good practice.

2. MAJOR FACTORS AFFECTING GOOD PRACTICE

A. Knowledge of the Standard

The first factor is the user's knowledge of the standard being used. It is important to know the scope of the standard, the background and history of its implementation, its strengths and limitations, and the important input parameters that affect result quality. The following factors affect accuracy of the standard [4]:

- Scope of application (range, situation, purpose, the range of levels calculated, model complexity and whether the method is for worst-case or average situations)
- Desired complexity of the method and the level of understanding of the physics of noise generation and propagation at the time of its development
- Expected form of implementation of the method at time of development (from hand calculations to single source-receiver combinations to 3D multi-point modelling)
- Clarity of documentation (description, formulae, details and test cases)

Standards are developed for different purposes and thus are more or less limited in their scopes. For example, the UK road traffic noise calculation standard CRTN-88 [5] was designed for determining noise insulation grants above relatively high levels of L_{A10} and thus is not optimized for lower levels and will provide less accurate results at these lower levels.

ISO 9613 "*predicts the equivalent continuous A-weighted sound pressure level … under meteorological conditions favourable to propagation from sources of known sound emission. … These conditions are for downwind propagation, … or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night. Inversion conditions over water surfaces are not covered and may result in higher sound pressure levels*" [6]. In addition, ISO 9613 states that the described method of calculating the ground effect "*is applicable only to ground which is approximately flat, either horizontally or with a constant slope*."

Knowledge about the background for the standard and the history of its implementation is important. Again, taking CRTN-88 as an example, it was developed at an early stage of calculation methodology, drawing on experiences for individual road-to-point calculations using a calculator or even a spreadsheet. When implemented in commercial noise calculation software for 3D multi-point modelling, it was discovered that the method was unclear and provided certain inconsistencies and challenges for automated result generation.

Knowledge of the above in addition to research and user experience provides an overview of the strengths and limitations of the methods and how input parameters affect result quality [7, 8]. For example, when using XPS 31-133 [9], the accuracy of the heavy vehicle velocity is important in determining the overall accuracy of the model. Knowledge of the standard and the results to expect are important was also highlighted in the recent changeover in Denmark from the 1996 Nordic road noise method to Nord2000 where the change from worst-case to long-term average levels in combination with revised calculations of the barrier effects meant great level differences [10].

B. Knowledge of the Software

The user's knowledge of the software, in particular calculation settings and their influence on result quality (e.g. range) also affects results. However, knowledge of how to optimise performance of the software is also important. In addition, the choice of software that matches a user's needs affects result quality.

As stated by Hepworth et al [11], noise calculations are becoming increasingly complex and data intensive as the scale and accuracy demands of noise calculations grow. Although environmental noise calculation capacity can be optimised by increasing the calculation capacity through networking computers or by increasing the calculation speed in the software [12]. For the largest calculations, in order to reduce the long processing times and significant investment in software and hardware, calculation software offers efficiency settings which reduce the complexity and number of calculations required. Calculation efficiency settings and their influence on result quality has been the topic of recent research [13, 14]. Calculation speeds can be reduced in several ways within a particular commercial software, although not without loss of result accuracy. How much accuracy is worsened by optimization is not widely documented, probably because the impact on results varies from standard to standard and from model to model. However, knowledge of how settings affect results and how they affect the performance of the software is important in selecting suitable calculation efficiency settings (see later).

Different commercial software are designed and optimised for a set of different needs:

- Scope of calculation tasks for which the software is optimized
- Speed of data handling and calculation
- Complexity
- Flexibility of modeling and guidance on use
- Frequency of use

Each of these factors determine suitability for a particular user or task. I.e. some software or configurations are ideal for small scale industrial noise models for environmental impact assessment with guided user input and a user interface that make it suitable for infrequent use by non-expert users. Other software are extremely powerful, capable and flexible but may be seen to be complex, making them difficult to use for some users even on a daily basis.

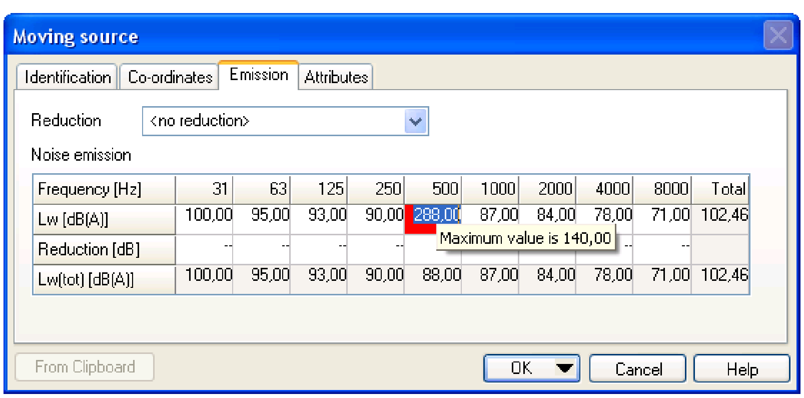

Figure 1: Some software provide limits on input data to help users correctly manually enter data and check data import.

In any commercial software, there are several user settings. As software is usually designed for different standards, input fields may be general and may not be optimized for a particular method. Some software is designed to guide the user through a particular standard while others give the user the opportunity to mix and match for greater flexibility for the advanced user. For example, some software such as Predictor help by providing input limitations (see Figure 1). Knowledge of how these settings affect results and how they affect the performance of the software is important. Some software provide manuals that include specific guidance on modeling in accordance with the method [15, 16].

C. Documentation of Software Functions and its Implementation of the Standard

Clarity of how to use a software is an important part of ensuring quality results. Software can be more or less intuitive for a particular application (see above). Assistance on use of a software can be found in technical documentation that traditionally have encompassed on-line help and written manuals. With the advent of broadband internet, suppliers have been able to develop their websites so that frequently asked questions and video tutorials that provide additional guidance to users are available [17]. Documentation can be supplemented by remote support, training sessions and user days. However, the authors claim that quality technical documentation is the most efficient tool for ensuring clarity on how to use a software.

Implementation of a standard into a software is a complex task and affected by the quality and extent of documentation of the standard itself and the availability of expertise in the standard [3]. Implementation involves interpretation of the standard and documentation of assumptions and interpretations made by developers during this process should be passed on to users of software so that they are aware of how the standard is implemented and to evaluate how this may affect modeling and the ensuing results [15, 16].

The software development community has for some time requested that standards developers provide sufficient documentation and develop test cases together with final calculation standards to reduce differences between different software packages. With this in place the Nordtest Method Framework for the Verification of Environmental Noise Calculation Software ACOU107 [18, 19] can be used to give users certification of compliance with standards. However, sadly, sufficient documentation and test cases are not available for the majority of methods used today [4]. In addition, experience has shown that there are difficulties in implementing the method for the quality assurance of software due to a lack of conformance of test cases with the requirements in the Nordtest method in all aspects including an insufficient number and extent of test cases, ambiguous test cases that even contradicted each other and, importantly, a lack of defined result tolerances. This makes it difficult to determine the quality of the implementation of the used method in the software.

D. Quality Assurance of Software Implementation

As stated above, implementation of a standard into a software is a complex task and affected by the quality and extent of documentation of the standard itself and the availability of expertise in the standard [3]. The software development community has for some time requested sufficient documentation and test cases to be developed together with calculation standards.

With this in place the Nordtest ACOU107 Verification Method [18] can be used to give users certification of compliance with standards. The Nordtest Method is an important development in ensuring the quality of independent implementations of methods by verifying that the software conforms with calculation methods. As the method states, "*In their effort to ensure high quality and reliability in noise level calculation the authorities should have test examples developed – with certified results and accepted tolerances – in parallel with or subsequent to calculation method development*."

In addition, there has been work in Germany to produce a national standard on quality requirements and test conditions for environmental noise calculation software. However, at the moment, there is no international method for developing calculation methods where the quality assurance of the implementation in software is defined. Such a method can be compared to the IEC sound level meter standard covering verification and documentation of compliance [20, 21].

E. Documentation of Software Settings in Calculation Results

Different software have a significant number of different calculation optimization settings [14]:

- Source Search Radius
- Dynamic Error Margin
- Minimum Section Length
- Contour Line Utilisation (search radius for using contour lines)
- Reflection Radius
- Simplification of Propagation
- Grid Interpolation for result presentation

The settings affect both calculation speed and result accuracy. Hepworth et al investigated how these user controlled settings affected result accuracy and calculation speed for the UK CRTN method [14] and noted that "*The effect of efficiency techniques on the accuracy of results is very variable*" and that "*there is no direct correlation between the reduction in calculation time and the level of error introduced*". It is the authors' experience that Dynamic Error Margin and Reflection Radius are the most efficient settings.

An evaluation of the impact can be done by statistically comparing levels obtained from calculations with no calculation optimization settings (giving the highest accuracy) to those obtained with calculation optimization settings used over a set of randomly selected receivers. This method, implemented in DIN 45687, requires a minimum of 20 points [22].

Table 1: *Recommended calculation settings for different tasks for Lima 7812*

Setting	Small scale models (environmental impact assessments of smaller industrial sites)	Large scale models (EU strategic maps)
Source Search Radius	3000 m	2000 m
Dynamic Error Margin	0 dB	3 dB
Minimum Section Length	0,01 (% of distance)	2 (% of distance)
Contour Line Utilisation	Typically 500 m (depends on topography)	Typically 500 m (depends on topography)
Reflection Radius	100 m	30 m
Simplification of Propagation	Off	On
Grid Interpolation for result presentation	1 m	1 m
Min relevant noise levels	0 dB	45 dB
Smoothing of Sources	0,1 m	5% of grid size
Smoothing of Buildings	0,1 m	5% of grid size
Smoothing of Contours	0,1 m	2 m

Thus guidance is required and, being software dependent, must come from the suppliers. Different settings are required or recommended for different tasks depending on the user's requirements to calculation accuracy and, to a lesser extent, calculation time. Thus, guidance from software suppliers, such as that shown in Table 1 from Brüel & Kjær, can only be treated as a guide and users are encouraged to gain experience in impact of their own decisions.

In addition, the user must document in reports of calculation results the software calculation optimization settings used so that results can be repeated. This can be eased where software automatically logs these software calculation optimization settings in connection with calculations and makes these easily accessible to the user.

F. The User's Analysis of the Quality and Impact of the Input Data

The impact of input data quality can be significant and studies have highlighted its impact with different calculation methods [23]. This has been done by evaluating the impact on results of the variance of an individual input data parameter with all other parameters invariant. The factors have been compared individually. This work has led to the development of the latest version of the WG-AEN Strategic Noise Mapping Good Practice Guide [24].

In addition, in some large-scale nose mapping projects, the amount and intense detail of the data has led to the simplification of the input data. When this has been done, evaluations of the impact of the simplifications have been carried out.

The European Commission/European Environment Agency workshop on target quality and input values requirements for noise mapping according to Directive 2002/49/EC [2] identified a strong need for guidance on input data collection as a major step forward in improving result quality. This should cover:

- Specifications for GIS input/output data and data collection
- Specification on degree of detail of the input data tailored for different noise mapping needs, e.g., strategic (global) noise mapping versus detailed (local) noise mapping for action planning
- A standard scheme to be followed for the collection of information on the datasets used and processing procedures used
- Specific conditions related to the definition and usage of "default" input data

This guidance is important and the European Commission is urged to pursue this approach to ensure good practice and improving the quality of output.

Due to the complexity of the modeling process, input data and methods used, and the user's analysis of the quality and impact of the input data, the user needs to analyse the quality of the input data and its impact on results. This can be done as simply as visually inspecting the results, comparing results with sound level measurements or assessing the impact of the data accuracy using uncertainty evaluation techniques. An evaluation of the impact can also be done in a similar manner to that described by DIN 45687 where the factor to be evaluated is input data simplification rather than calculation optimization. Following this logic, a set of minimum 20 randomly selected receivers could be recommended for a comparison of results from crisp models with the most accurate data sets and those with simplified input data.

3. GOOD PRACTICE

Several methods are available to ensure good practice and improve the quality of output through such methods as standardization and documentation, training and user certification. These are listed in Table 2 together with additional good practice identified by the authors.

Table 2: *The authors' recommendations on good practice in the use of noise mapping software*

What	How
Gain knowledge of the standard to determine if and how best to simplify model input data without undue loss of accuracy. Investigate the calculation method's sensitivity to input parameter variance: which input parameters influence results the most and in what situations (users)	• Consult WG-AEN Strategic Noise Mapping Good Practice Guide [24] • Consult national guidance such as that provided for Dutch railways [25] • Consult conference papers describing experiences and accuracy implications [23] • Perform tests on the effects of simplifications using one's software and selected method and

	on typical or actual cases. Tests of simplifications can be done as described by Hepworth and Trow [14]
Recurring user certification of environmental noise assessors (legislators)	Some countries such as Denmark require recurring user certification of environmental noise assessors for use of their work, including results from their calculations in legal issues
Develop test cases and document the standards (method developers)	Improves knowledge on scope and accuracy of the standard and enables a better and less variable implementation of the standard in software, giving more repeatable results
Demand test cases and correct documentation of standards in the development and selection of new methods (legislators)	Improves knowledge on scope and accuracy of the standard and enables a better and less variable implementation of the standard in software, giving more repeatable results
Develop (additional) test cases (users)	Test cases where multiple models with different levels of detail of input data can be compared in order to get an overview of the impact of results Improves knowledge of the standard
Compare results with noise measurements (users)	Compare results from measurements and calculations based on the same situation [26, 27] Improves knowledge of the standard
Knowledge of how calculation settings affect the performance of the software. Know also how they affect results (users)	• Read the software's manual • Attend initial training offered by the supplier • Perform tests on the effects of simplifications using one's software and selected method and on typical or actual cases (e.g. as described by Hepworth and Trow [14])
Select a software that matches the user's needs (users)	• adequately documents the software's functionality and documents • documents how the standard is implemented in the software • complies with software QA and verification methods such as the Nordic method • quality and extent of guidance and advisory documentation • matches the most frequent use situation
Document in reports of calculation results the software calculation optimization settings used (users)	• attending training offered by the supplier • reading the manual This ensures that results can be repeated
Preferred calculation optimization settings (users): • intelligent use of Dynamic Error Margin and Reflection Radius as the primary factors • careful use of other efficient settings.	Initial guidance on which settings are required or recommended for different tasks should be supplied by the software suppliers. However, the user must take final responsibility for choice of settings depending on the user's requirements to calculation accuracy and, to a lesser extent, calculation time.
Analyse the quality of the input data and its impact on results (users)	Consult: • WG-AEN Strategic Noise Mapping Good Practice Guide [24] • national guidance such as that provided for

	Dutch railways [25] • conference papers describing experiences and accuracy implications [23] • Perform tests on the effects of data simplifications using one's software and selected method and on typical or actual cases. These tests can be done as described by Hepworth and Trow [14] by comparing results with those using precise data sets for a selection of different individual receiver positions in order to get an overview of the impact of results
Determine optimal simplification of input data (users)	• Evaluate the capacity of your software and computer and the requirements for result accuracy (which may vary from one receiver position to another within the same model) • Visually inspect the results • Compare results with sound level measurements • Assess the impact of the data accuracy using uncertainty evaluation techniques (e.g. by evaluating each input data simplification at minimum 20 randomly selected receivers) • See also "Analyse the quality of the input data and its impact on results" above
Develop further guidance on input data collection and use in different applications (legislators)	Legislators such as the European Commission should provide guidance on input data collection and use in different applications. Guidance should cover: • Specifications for GIS input/output data and data collection • Specification on degree of detail of the input data tailored for different noise mapping needs, e.g., strategic (global) noise mapping versus detailed (local) noise mapping for action planning • A standard scheme to be followed for the collection of information on the datasets used and processing procedures used • Specific conditions related to the definition and usage of "default" input data • A fixed methodology to attribute population exposure to noise levels This guidance is important and the European Commission is urged to pursue this approach to ensure good practice and improve the quality of output. When this is published, the authors strongly recommend its use
Set up guidance on the competent use of noise assessment methods (legislators)	• The relevant quality and quantity of input data • Guidance on how to use, extract, extrapolate and manage input data

	• Software calculation settings • Software use and modeling

4. CONCLUSIONS

Users, software developers and method developers can influence the quality of the result from noise mapping software in the following areas:

- the user's knowledge of the standard
- the user's knowledge of the software
- the clearness of the documentation of the standard
- documentation of software functions and its implementation of the standard
- quality assurance of software implementation
- documentation of software settings in calculation results
- the user's analysis of the quality and impact of the input data

Several methods are available to ensure good practice and improve the quality of output through such methods as standardization and documentation, training and user certification. These have been identified together with additional good practice identified by the authors.

As it can be seen above, the software developer and the user share the bulk of the good practice demands. However, also method developers need to provide guidance for implementation.

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