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Managing Risk by Utilising an Integrated Approach to Quality Assurance During Strategic Noise Mapping

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Abstract: With the proclamation of the END (2002/49/EC), the process of noise mapping and action planning has begun around Europe. As the development of strategic noise maps is arguably a new experience for many end-users, the first round of noise mapping could lead to uncertainties within many aspects of the process. Noise maps represent a baseline for the implementation of noise management systems and systematic errors within the noise maps could reduce the effective implementation of the whole management system. The extensive range of data inputs required in strategic noise mapping are usually obtained from different data sources and as such, cataloguing with the use of metadata is key. The implementation of a quality assurance system is imperative to maintain consistency between technicians and within multi-disciplinary teams. It is also essential to ensure the control of processes and the ability to review inputs, intermediaries and deliverables. A similar approach may also be applied to calculation and post processing of noise levels. This paper presents collective experience of the implementation of quality assurance procedures used in several EU countries during the successful completion of projects within the first round of mapping.

1 Introduction

With the proclamation of the Directive 2002/49/EC (END) [1], the process of strategic noise mapping and action planning has begun across the EC Member States, and also the Candidate States. Summaries of the 2005 MS Reports, published on CIRCA by the Commission [2], indicate that for the first round of the Directive assessments are being undertaken for over 82,000 km of major roads, 12,000 km of major railway, 74 major airports and over 160 agglomerations containing some 120 million inhabitants. It is arguably reasonable to suggest that strategic noise mapping to this extent has not previously been undertaken. It is also not unreasonable to suggest that the level of experience, availability of input data and understanding of the process varies significantly across member states.

Under the approach set out within the END, the strategic noise mapping represent the baseline evidence base for the management of environmental noise, development of actions within the MSs, and development of Community actions. Throughout the process there will be the potentially conflicting requirements for good quality robust results, and minimisation of costs. If one considers the input data requirements for the EC recommended Interim Methods, or existing national methods, over large areas of the urbanised regions of the EU, the resulting requirements for the collection and collation of input datasets becomes extensive.

The scale of these challenges may lead to time and cost savings being sought at various stages within the process. Within GIS, these requirements may lead to a desire to adopt “low cost methods for data collection”, or a desire to utilise existing datasets which may offer a “reasonable fit” to the requirements, or the extensive use of WG-AEN GPG Toolkits [3]. Within the noise mapping software it may lead to a desire to dramatically reduce the resolution of the datasets to reduce object counts, or use many time saving efficiency techniques to help reduce processing time [4].

Experience gained during the delivery of a number of strategic noise mapping projects has lead to the development of a quality assurance process to aid with the managed development of the collated input datasets and finalised acoustic model. The system maintains consistency between technicians, and within multi-disciplinary teams spread across multiple organisations and geographically. It essentially also controls the process and provides the ability to review inputs, intermediaries and deliverables. The QA system was later extended to cover result checking, post processing and analysis.

2 Overview of the noise mapping process

Each noise mapping process can be described in the 7 main stages as shown on Figure 1.

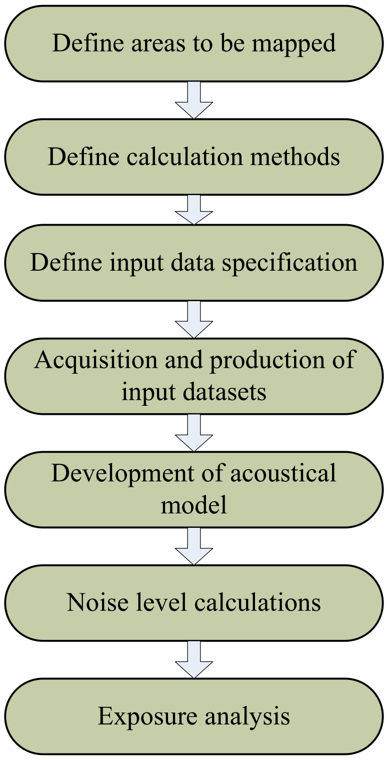

Fig. 1. Overview of the noise mapping process

Each of the stages includes many decisions, and may be talked in many different ways, and each may potentially have a strong impact on two key aspects of the noise mapping: (1) uncertainty within the assessed noise levels, and (2) extent of the required project budget. The range of possible “solutions” and the degree to which cost and uncertainty may be traded against each other may help to explain why the figures widely published for noise mapping projects range from € 0.2 to € 2.0 per inhabitant. From a technical perspective it is suggested that the project budget can be strongly influenced by the decisions made regarding:

- Definition and resolution of the input data;
- Conversion of the data and later post processing;
- Simplification strategies to speed up calculation; and
- Management of results uncertainty.

The extent of uncertainty within the assessed noise levels is influenced by the various sources of uncertainties, which can be grouped into the four main areas [5]:

- Estimation of uncertainties in model inputs and parameters (characterisation of input uncertainties);
- Estimation of the uncertainty in model outputs resulting from the uncertainty in model inputs and model parameters (uncertainty propagation or sensitivity);
- Characterisation of uncertainties associated with different model structures and model formulations (characterisation of model uncertainty);
- Characterisation of the uncertainties in model predictions resulting from uncertainties in the evaluation data (uncertainty of evaluation data).

A secondary issue within the noise mapping process is the (un)intentional usage of the various simplification strategies and efficiency techniques available to speed up the calculation process, which may have significant impact to the accuracy of the calculated results [4].

In common with any other quality assurance procedure, the developed noise mapping QA procedure needed to cover every possible processing step, with necessary tracking information, and minimum documentation requirements. The right balance needed to be struck between usability and control. It was also important that it be flexible and wide ranging enough to be effective in a typical multi-disciplinary process with noise mapping and geo-processing teams in collaboration. In this context it proved to be successful in helping to deliver technical interoperability whilst maximising compliance with appropriate standards, use of best practice and traceable project deliverables.

3 Overview of the QA procedure

The QA procedure was designed in the context of an electronic data management process, which functions with initial datasets, intermediaries and final datasets all in electronic format. The QA procedure was designed such that each team member could access the relevant element for the stage in the process they were working on, and that it supported remote working, web/VPN access and inter office collaboration.

3.1 Stage 1

The main task of Stage 1 was to ensure that the areas to be mapped had be properly defined, and that the datasets provided the required coverage and had appropriate content.

In most cases the required area definitions are in line with Toolkit 1 of the GPG v2 [3]. For agglomerations the boundaries of the strategic noise mapping assessment area must be equal to areas of agglomeration, whilst model data is normally required outside this assessment boundary. For mapping of the major roads or railways, the area boundaries may be obtained from an estimation of the L_{den} = 55 dB and L_{night} = 50dB noise contours.

Once the areas are determined, they set the mask for data capture, collation and concatenation in the next stage.

3.2 Stage 2

Within many Member States, the task of defining the method of assessment is already undertaken within the national legislation transposing the Directive into Regulation. The END presents two broad options:

- Member States national computational method, or
- Interim methods set out in the END.

This stage remains of key relevance for two reasons:

- National legislation within some Member States retains the option of national or EU Interim methods, thus a selection is required;
- Adaptation:
    - The recommended Interim Methods must be adapted in line with the EC decision [6];
    - Many national methods require adaptation;

Thus an important task is a clear statement of the methodology to be used, including any necessary adaptation, as this sets the requirements for the data schema design and list of input datasets.

A typical example regarding input datasets is the use of long-term meteorological data for the determination of the occurrence of favourable sound propagation conditions. Whilst the recommended interim methods require this information, some national methods such as CRTN [7] or RLS-90 [8] do not.

3.3 Stage 3

With knowledge of the required area of coverage, and the method of assessment to the utilised, it was now possible to develop an input data schema specification.

Despite the fact that the data required for producing acoustical model layers are more or less similar in every noise modelling project, the detailed requirements vary according to the calculation method being used, the noise mapping software being used, the resolution of different input datasets and even the projection system being used. Because of these significant detail changes, it is necessary to produce a data specification schema for each project.

The input datasets required are usually classified into two categories:

- Source data, i.e. definition of the position and characteristics of the noise sources; and
- Pathway data, i.e. definition of the environment within which propagation occurs.

Broadly it can be said that the recommended interim methods for road, railway and industrial require similar information for the definition of the pathway, whilst the source information required is unique to each method.

The data specification then sets out a detailed list of the model layers required, and a full set of object and attribute definitions, including and relevant constraints or object geometry rules. Experience gained through the development of several such specifications clearly indicates that this is a key crossover document which needs to be developed in a combined approach with both GIS and noise modelling expertise. The resultant specification then enables full development of GIS datasets which may be successfully imported into the noise mapping software and processed through the calculation kernel without any secondary issues.

3.4 Stage 4

Due to the wide range of input datasets required for strategic noise mapping, data acquisition is often performed by third parties, or existing data acquired for other purposes is pressed into service.

The base ground model layers used to develop the acoustical pathway are often obtained from State surveying and mapping authorities with predefined formats and resolutions. Decisions will then often be required as to how to process this data to make it most efficient for the noise modelling. Automated processing of the datasets is often required, and final output resolution and consistency with the input datasets need to be managed.

Source data for roads and railways is often held by the relevant state agencies, private companies or private traffic consultants. The original format and definition of these datasets is often significantly different from the format required within the noise modelling process. Processing of these datasets will often be a manual or semi-automated process, which requires documentation to provide traceability and repeatability.

Possible source datasets for industrial processes are set out within the END. The approaches set out include the use of measurements to help develop a source model, through to the use of pre-defined levels of emission from publicly available data sources.

3.5 Stage 5

At the completion of stage 4 a collection of data layers are available in GIS format which have been processed from raw data and general geographical data files to meet the defined specification. At this stage the data layers are to be transferred into the noise mapping software environment, and a number of pre-flight checks undertaken to ensure smooth processing of the models and the successful delivery of noise result datasets.

3.5.1 Input checks

This initial check is undertaken following receipt of the finalised GIS datasets. Checks are undertaken for the following:

- Conformity (verification that the datasets are in line with the data specification document);
- Coverage (whether data covers the relevant project extents); and
- Content (whether the correct data has been provided and contains the correct attribution).

3.5.2 Data conversion checks

The GIS datasets are then converted to the proprietary file format supported by the noise mapping software system. The results of each conversion are checked, followed by additional testing of the objects within the noise application. The QA procedure covers the stages of the process, and has built up a number of common issues and resolutions to help streamline future projects.

Initially the acoustical model layers are checked individually, and once signed off they are then tested in combination to ensure that the 3D model environment is properly resolved when all the model layers are combined. Interaction between bridges, roads, railways, building, embankments and hillsides (etc) are checked. Figure 2 shows an example issue which may arise.

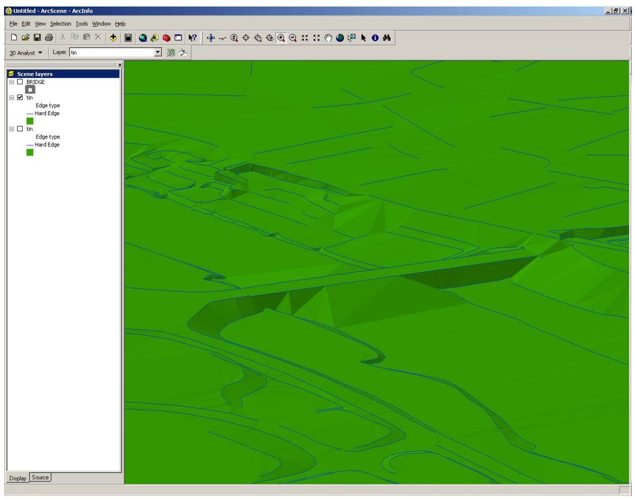

Fig. 2. “Wrong” interpretation of the bridges and terrain over a river

3.5.3 Preliminary calculation checks

In most large noise mapping projects so called “tiled” mode calculations are preferred, Figure 3. This is due to several factors, including: the size of the acoustical model; the extent of the project area; the software architecture; and the desire to balance processing across multiple computers. Following the automated creation of the multiple model tiles, preliminary checks were undertaken for receptor points inside each model tile to confirm an error free run.

This approach helps to avoid any requirement for repeating time consuming final grid calculations.

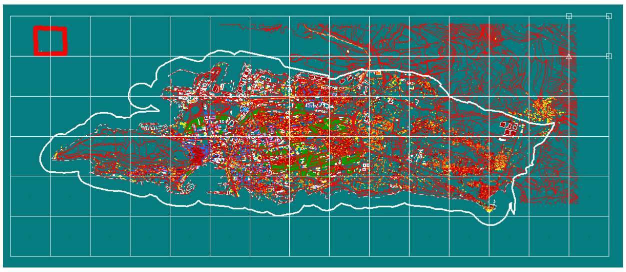

Fig. 3. Example of tiled calculation

The EU recommended Interim Methods, and most national methods, are based upon a semi-empirical approach to mathematically describe sound propagation. By knowing the fact that the calculation methods were not written with the intention of transformation into a 3D software environment, the use of the QA testing of settings within noise calculation software becomes imperative. The use of the QA calculation set-up inside the LimA noise mapping application is shown on Figure 4.

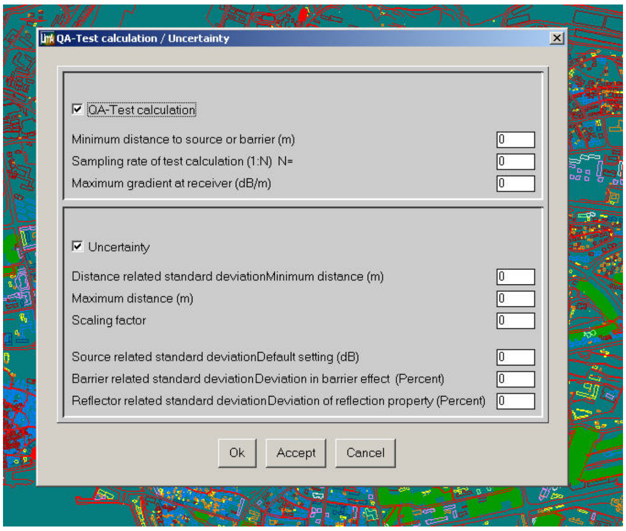

Fig. 4. LimA QA Calculation set-up

3.6 QA of noise calculation process

WG-AEN GPGv2 [3] recommends that two sets of calculations should be carried out for strategic noise mapping:

- Calculation No. 1 - For noise contour mapping

  For noise contour mapping and the determination of areas affected by particular bands of noise, calculation of noise levels must be grid-based. These calculations should include at least all first order reflections. Generally, the grid spacing should be no more than 10 metres in agglomerations.

- Calculation No. 2 - For assigning noise levels to buildings

  For assigning noise levels to buildings, noise levels should be calculated at the facades of the buildings. (at 0.1 metres in front of the facade). Such calculations must exclude reflections from the facade in question, in compliance with the requirements of the END that such levels shall be incident ("free field") noise levels. It is recommended that at least first order reflections from other facades or objects should be included. It is suggested that a spacing of 3 metres between calculation points around the facade is likely to be appropriate.

With the presumption that the noise mapping applications are verified with the current standards in the field of the environmental noise modelling software [9, 10] the QA of the calculation process can be focused towards the user controlled calculation parameters that directly influence the results. Namely, when performing 3D noise mapping calculations of large areas, calculation time is an important consideration. Present day software packages can apply numerous options to accelerate calculation time, so if there is no understanding of the impact of each of those options, there is an increased risk of introducing significant uncertainties into the final result sets.

Recent studies have investigated the impact on time and uncertainty of a number of user calculation settings across five leading noise mapping systems [4]. To assess the uncertainty introduced (cost), the results obtained were compared to the results obtained for "benchmark" settings designed to produce the most accurate result possible from each software system, whilst the time taken was also compared to the time taken for the "benchmark" results (benefit). The final results point towards the fact that the inappropriate use of some calculation options may introduce uncertainty of over 5 dB(A), 95% CI. This would be in addition to any uncertainties introduced by the quality of the input datasets [5, 11]. The major issue is the fact that in most of the cases, the end users of the noise mapping software weren't consulted about the possible calculation settings, and the possible uncertainties which can arise from the "shortest calculation time" parameters are not documented.

The QA procedure under discussion thus includes confirmation with the end-user on the proposed calculation settings, and a corresponding description of the impact on the final calculated levels. By this means, the end user of the noise mapping results can directly restrict the uncertainty of the calculations and provide some form of contractual control mechanism on quality.

3.7 QA of exposure analysis

Following completion of the assessment of noise levels, the results are first reviewed to that they are consistent and in line with expectations. Particular attention is paid to the results around the boundaries of the calculation tiles and near the assessment boundary.

The area, dwelling and population exposure analysis based upon the results of the strategic noise mapping may then be undertaken within a GIS system, or within some of the noise mapping applications. Wherever the analysis is undertaken, the crucial task within the exposure analysis is the proper distribution of inhabitants into the residential buildings. It is therefore necessary to correctly define the attribution of building objects in the data specification, and special attention should be paid to mixed urban areas, where residential occupancy of building often starts from the 1st floor. Depending upon the nature and format of the population information, and the complexity of the built environment, it may be appropriate to bring in a GIS specialist with expertise in demographic assessments to ensure that the population exposure assessment is undertaken in a robust manner.

5 Conclusion

This paper describes an approach to the process of strategic noise mapping delivered through the successful implementation of a Quality Assurance Procedure. This procedure promotes a staged approach and supports team working within a multi-disciplinary and multi-company project group. The described methodology demonstrates the applicability of the system in every, even simple, noise mapping projects, and points to a possible approach for an accreditation schema in the field of quality assurance of noise mapping consultants.

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