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Production of Scalable Environmental Noise Maps Utilising Interoperable Datasets to Aid Integrated Policy Making

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Abstract [548] The forthcoming production of large scale noise mapping to meet the requirements of the EC Environmental Noise Directive (2002/49/EC) and the future need to integrate and manage extended datasets for the detailed use of the proposed Harmonoise methodologies, are leading to a thorough reappraisal of the data management requirements for acoustics calculations. This paper sets out how current initiatives in the spatial data industry such as the development of spatial data infrastructures and GIS based geodatabase technology can, when combined with integrated acoustic calculation engines, be used to deliver cost effective, quality controlled, environmental noise maps to meet the new scalable mapping requirements. In addition, the paper will set out how the use of interoperable datasets can ensure that environmental noise is integrated with wider environmental, socio-economic, transport and land-use planning issues at the policy and technical level. Whilst this paper focuses on and refers in the main to the experiences of the EU, the principles and concepts discussed have a global relevance.

1 INTRODUCTION

On the 25 June 2002 the European Parliament and the Council of the European Union (EU) published Directive 2002/49/EU[1] relating to the assessment and management of environmental noise (the Directive). The Directive lays down the requirement for a large scale noise exposure assessment exercise within Member States. The results of this exercise are to be used in the development of both action plans within Member States, which are to be submitted to the Commission, and community measures aimed at reducing or controlling environmental noise with the ultimate end of complimenting the EU objective of achieving a high level of protection of the environment and of health.

If relevant and meaningful noise action plans are to be developed a detailed understanding of the public exposure to environmental noise is required. The scale and breadth of this noise study is such that the most likely means of delivery, which is suggested in the Directive, is via a series of software based large scale noise mapping projects. The scope, resolution and delivery of these maps needs to be seen as a first step along this path, hence they must be planned within this wider framework to ensure relevancy towards the remainder of the stages within the Directive.

In order to ensure that the ultimate ends of the protection of the environment and health are met, it is vital to ensure that the measures developed within the EU, and contained within the Member

State action plans, not only reflect the true relationship between environmental noise exposure, health and annoyance effects, but also that those noise measures are compatible with other environmental and socio-economic policies and do not perpetuate, or produce, a negative impact or effect through some means other than noise, especially where very significant impacts can arise as a consequence of implementing a measure. In short, those measures must be sustainable.

In practical terms, the knowledge required to develop sustainable environmental noise control measures will be derived from a combination of information sources: the nature of the noise source, the nature of receptor and the effect on the receptor, the nature of the source/receptor path, the effectiveness of any mitigation measures and importantly the nature of any associated or indirect effects on the source or receptors as a result of the noise reduction or control measures.

In the modern age this information is likely to be derived from electronic data. By implication, therefore, it is this data which must meet acceptable levels of quality to ensure that accurate, valid and sustainable decisions are made in the management of environmental noise. In short, the validity of the knowledge upon which decisions are based, and measures developed, can only be as good as the accuracy of the information provided from results data. A challenge is therefore presented to the noise community - how to ensure the delivery of sufficiently high quality information to policy makers using cost effective, large scale, noise assessments, such that effective noise measures can be developed with minimal 'external' impact. A solution is to share relevant data with other professional communities to ultimately reduce costs, and to ensure a consistent and joined up view of the real world, so as to understand and avoid indirect negative effects as a result of noise control measures.

These demands are increasingly being met through technological solutions and an increased awareness of the benefits and technical requirements associated with joining up policy and the exploitation of a common component inherent within environmental noise, and associated environmental and socio-economic disciplines which link them together – *geography*. So, are the noise community exploiting this?

2 THE REQUIREMENTS OF THE ENVIRONMENTAL NOISE DIRECTIVE

Commonly referred to as the Environmental Noise Directive (END), the Directive aims to compliment the EU objectives of *"achieving a high level of protection of the environment and of health* [by initially] *achieving a common understanding of the noise problem"* within Member States through an assessment of major noise source emissions, associated with transport and industrial activity, and then through the *"adoption of action plans by Member States"*. In order for this to be achieved, the Directive recognise the need to augment the current *"lack of reliable, comparable data regarding the situation of the various noise sources"* by undertaking an assessment of environmental noise exposure, through noise mapping, across Member States and using the results as a basis for the adoption of action plans to prevent and reduce environmental noise, where required, and to aim at providing a basis for the development of community measures to reduce noise. The mapping exercise is to be completed by 30 June 2007 and reported to the EU by 30 December 2007. The Action Plans are to have been drawn up by 18 July 2008 and to be reported within 6 months, by the 18 January 2009.

The objective of the Directive is to define a common approach to the assessment of environmental noise as currently a great diversity of assessment methods, criteria and policies exist across member states; not to mention attitudes to environmental noise. To assist in this process a series of research

projects are currently underway under the auspices of the EU Noise Expert Network, within the CALM Network[2], and run by the Working Groups on "Health and socio-economic aspects", WG-HSEA, and "Assessment of exposure to noise", WG-AEN. This work is aimed at providing a common set of research evidence and implementation guidance on noise impact, community response, effect of mitigation measures, practicalities of noise mapping and many of the other factors which need to be considered when drawing up a noise action plan to help improve community conditions. Alongside this work is other research work looking into description of noise sources, and development of new calculation methods. The Harmonise[3] work will be reported elsewhere and through the Imagine[4] project will provide a common framework of assessment of environmental noise along with guidance on its application.

3 ENVIRONMENTAL NOISE POLICY AND TECHNICAL DEVELOPMENT

Viewed from an historical perspective there are probably more ongoing research projects into environmental noise than at any previous time. These are increasingly being carried out by pan-European teams within an EU backed infrastructure. As mentioned above we have the CALM Network which has spawned the Noise Expert Network, and two Working Groups, each of which is currently managing a number of research projects.

The WG-HSEA is looking to provide evidence and guidance on how noise affects the population, through the establishment of dose-effect relationships and cost-benefit analysis, to inform socio-economic impacts to be carried out. Whilst the WG-AEN is currently producing guidance on implementation of the Interim Calculation Methods, to be used in some EU Member States during the first round of noise mapping, and more universally a "Good Practice Guide for Strategic Noise Mapping"[5] which highlights many of the practical difficulties which will be encountered when a coherent, cross discipline data management framework is not in place.

The other main driver in the technical development of the Directive is the Harmonoise project, which is now transitioning into the new Imagine project. Harmonoise has developed a detailed background and proposed methodologies for calculating road and rail noise in the environment. These have come about from many avenues of research and measurement. The next stage, where Imagine takes over, is to transition the Harmonoise methods in the real world and offer up practical advice and guidance on the methods application for the second round of noise mapping in 2012. Imagine is also extending the scope of Harmonoise and looking into Industrial and aircraft noise calculation methodologies.

From the information published regarding the Harmonoise methodologies at the time of writing, it is apparent that the calculation methods offer the possibility of higher levels of accuracy than most of the pre-existing calculation methods currently used across Europe. It is also clear that they require a range and complexity of input data often way beyond that currently used in many Member States. This will lead to a whole range of data sourcing, capture and management issues not currently considered with existing methods.

Finally, there are also a number of City collaboration projects which have a range of aims and deliverables, some of which will provide further evidence on dose-effect and socio-economic factors, others on technical issues, and one which even suggests it will develop a cross discipline software system and go to market in competition with the established market leaders in each disciplinary area. Projects such as HEAVEN[6], ISHTAR[7] and ENVIBASE[8] are all looking into integrated impact assessments, monitoring and reporting of factors such as noise, air quality, traffic

volumes and flows, pollutant impact on historic buildings, transmittal of information to the public in real-time and development of sustainable development strategies. Projects such as EQUAL are looking into ways of communicating the captured data live, or near live, to the local population.

An increasing number of these research projects are now beginning to issue papers through their own websites, or through CIRCA[9]. Whilst many are notionally working within the same framework under the CALM Network, in reality there appears to be a fractured approach to the work carried out, with little cooperation between research teams, or pooling of information and resources. This is exemplified even by something as trivial as attempting to discover all the relevant published work from the various projects and steering groups.

This multi-dimensional approach to research work across Europe is not unique to noise, the CLEAR[10] website listed some 11 current research projects on air quality assessment, many of which were linked with other projects. A brief look into the work being carried out showed similar pools of related information, often disconnected from other work in the area, or from other technical disciplines within the locality.

Whilst the search carried out was not exhaustive, there was little evidence that the developed systems linked into any form of geo-database engine or linked to datasets across the organisation, except in one case, the Berlin Heaven project[11] has an Oracle database system underneath managing the various data sources and outlets in a system developed by IVU-Umwelt.

Looking at the work which has been carried out to date, it is clear that the complexity of noise mapping and data requirements exceeds that which has typically been applied to air quality mapping. You then add in the large numbers of stakeholders associated with the generation of environmental noise, the large numbers of people affected by environmental noise and by implication, the number of organisations who have an interest and or a role to play in the management of environmental noise and you enter an area where the cross-discipline coordination of data management, licensing and control become the major barriers to mapping development. This produces a problem with a level of complexity beyond the functionality of most specialist noise mapping software and the remits of noise specialists. If you then add into this the requirements for managed updates to the maps within the subsequent five years, rather than rip and replace, and linking and publishing the model and results data to public forums, the solution increasingly points those areas being addressed by the GI community with the latest generation of GIS.

The work is also showing the complexity of environmental noise and the challenges associated with producing a common noise assessment tool which accommodates the wide variety of parameters likely to influence the validity of a noise exposure assessment. There is also a fundamental problem with inconsistent or poor quality data, or simply a complete absence of data altogether. So how might these obstacles be overcome when they must be common problems to other professionals in other communities and how could the geographical component provide a solution?

4 DATA IN ENVIRONMENTAL NOISE ASSESSMENTS

The requirement of good quality data for informed decision making is acknowledged, so let us turn attention to the data used in environmental noise assessments, specifically involving predictive calculations using noise mapping software – the types of data required, its origin and creation and to see whether any of the existing solutions can solve the current issues.

Noise exposure results are derived from comparing mapped calculated noise levels (or derived thresholds) and comparing the different levels of noise at the locations of the receptors. The calculated noise levels themselves are generated by calculation software in accordance with a specified calculation method, which in turn relies upon input data providing details of the locations and characteristics of noise sources and the characteristics of the surrounding physical environment which affect propagation.

In order to develop a suitable noise mitigation scheme to be included within an action plan each potential measure would need to be assessed. A typical scientific approach for each proposal would be to modify one of more of the original input parameters, and rerun the assessment to assess potential changes in outcome. This process then iterates until a suitable balance between an understanding of the measure and its likely benefit are understood. In practice this will be likely carried out using the noise maps and running a series of potential noise mitigation scenarios. It is clear therefore that the quality of the exposure assessment and effectiveness of noise control measures ultimately depends on the quality of the input data and validity of the calculation method; both in its own right and with respect to the available data, both ideally being the subject to appropriate standards. Whilst the development of the Harmonoise method provides a medium to long term solution to the second point, the current availability and quality of data which will be required for the development of large scale maps is far from ideal.

The quality of noise assessment data can generally be regarded in categories. There are those qualities which relate specifically to the acoustic assessment (e.g. characteristics about the noise source) and those which relate to the location of a particular feature with respect to other features (e.g. the location of a noise barrier in relation to a road). There are also qualities which relate to the dataset in general, describing contextual information such as currency and ownership. There is a natural tendency for the noise specialist (as there is in other disciplines) to focus on the acoustic qualities of the data, potentially at the expense of the geographical and contextual quality of the data in relation to other datasets being integrated in the same assessment. These geographical and contextual qualities, however, can have a significant impact on the accuracy and validity of noise assessments and the development of noise control policies. So, how can dataset consistency and quality be controlled in noise assessments?

5 SPATIAL DATA INFRASTRUCTURES

As previously discussed, the common link between virtually all datasets used or generated in acoustic modelling and exposure assessments is the geography of the assessment area, hence the datasets can also be seen in a more general term as types of geographic information (GI). Studies suggest that 80%[12] of data contains a geospatial component, not only enabling it to be mapped but also to be managed in specialist geographic information systems (GIS). It is the development in recent years by the geographic information community of spatial data infrastructures (SDIs) that can benefit the European noise community as large scale assessments loom.

Spatial data infrastructures are being borne, around the world, out of a very simple requirement. There is an increasing need at the highest political levels to develop knowledgeable and sustainable solutions to manage our world. A common thread is therefore required to link information about our world together; this presents itself to us in the form of geography. But, the costs of capturing geographical information at a sufficiently high resolution so that truly informed decisions can be made are prohibitively expensive for many disciplines. Fortunately, however, many disciplines

require similar types of information about the same real world features and are therefore beginning to work together to capture and maintain a single definitive set of data about specific sets of features which can then be shared amongst multiple end users. Because the data is definitive and consistent a common view of the world is shared allowing for consistent decision making. The effective use and management of such interoperable GI is therefore key to sustainable and integrated transport and land use planning.

Taking this back to the context of environmental noise, where often data currently doesn't exist or is not of sufficient or known quality, think how many other disciplines also use data relating to transport movements, topographical features, the location of buildings and the distribution of people in the community in relation to the transport infrastructure or proximity to industrial premises. There is a huge potential to link with other disciplines.

The technology exists to enable this to happen. Open standard GIS can easily be linked to local or remote geodatabases serving multiple users, ensuring assessments are undertaken with standardised and interoperable datasets. The adoption of GML (Geography Markup Language) and geodatabase technology are helping this to be achieved with definitive data models being built as a result. The GI community, through working with numerous disciplines, are setting about constructing the building blocks to enable SDIs to be developed. At a European level the most significant is INSPIRE (INfrastructure for SPatial InfoRmation in Europe[13] and in the UK, the four home nations are currently developing or evaluating the need for GI Strategies[14 15 16 17].

The challenges in implementing SDI's, whilst conceptually simple, are not straightforward. As with most new developments the challenges are often manmade – lack of understanding, lack of political will or reluctance to change old practices - but a number of projects of relevance to the directive mapping are demonstrating that SDI's at various scales can be achieved and the benefits are being seen.

6 EXAMPLES OF SPATIAL DATA INFRASTRUCTURES AND INTEROPERABILITY

SDIs and interoperability rely on agreed data standards. Such standards are conventionally defined in a data model, setting out the contents of the datasets along with appropriate quality information. Such data models also facilitate the holding of metadata, a key component in the quality control of GI. An increasing number of noise projects or projects with a relevance to environmental noise management have or are in the process of being setup utilising management processes and techniques from the GI community.

The United States Environmental Protection Agency (USEPA) commissioned the creation of an industrial geodatabase model[18] to assist in the management, licensing and environmental assessment of industrial premises under its jurisdiction. The data model allows for single definitive records for key parameters to be recorded once and used multiple times. The data model also allows appropriate objects to be assigned to features therefore allowing more than one physical representation e.g. an emissions stack can be represented as a point for the purposes of an emissions assessment and as a polygon with actual dimensions for purposes of facilities management. The Environment Agency of England and Wales (EA) are currently evaluating similar methods or managing information relating to industrial premises.

In England, John Hinton at Birmingham City Council has pioneered the development of large scale city wide environmental noise mapping[19]. The first city wide noise mapping system was

established in 1999 using LimA software. The project was largely implemented as a feasibility assessment, testing whether appropriate input information could be acquired for a strategic noise mapping exercise. Whilst the project proved the concept, limitations in the quality of data were observed and as time has passed, the currency of the information held in the system is no longer deemed fit for the increasing demands of environmental noise information by planning, education, leisure and other corporate departments. In order to rectify this the City Council is implementing a second updated system, which will be built around a project specific spatial data infrastructure and data model, working in partnership with data owners such as Network Rail, Birmingham City Airport and Birmingham's Transportation Department. The project is being managed as a model spatial information management project with a full requirements analysis, data audit and standards identification being undertaken and agreed with stakeholders at the outset.

In Hong Kong the NEST system[20] has been developed by ERM for the Hong Kong Environmental Protection Department which uses an ESRI ArcView/ArcGIS user interface, geodatabase archive and LimA software noise calculation system. This integrated system is currently being extended to an ASP.NET application to enable cross department access to the model and results data without specialist acoustics knowledge.

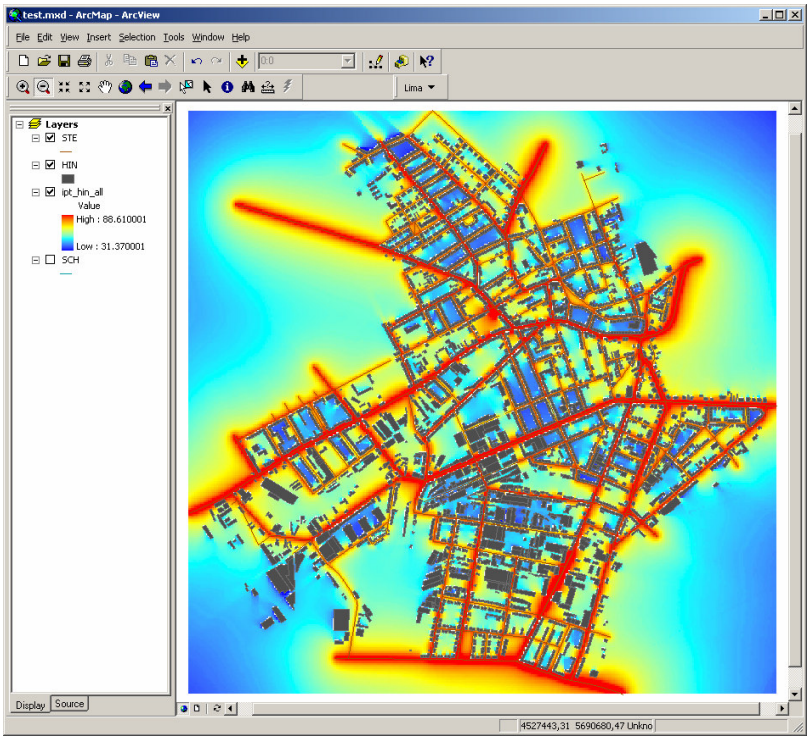

Figure 1: *LimA menu add-in for ArcView from IVU*

In The Netherlands the GeoNoise[21] software has become the default standard for retaining and calculating noise and geographical data relating to all industrial sites within the country. Site operators and their agents interchange GeoNoise files with the government agency when dealing with noise issues. The same developers have also produced the GIS based Silence[22] system for the Dutch Ministry of Transport, where geo-information, road traffic data and results sets are stored in a geodatabase. When new scenarios require calculating the model information is pushed on demand

to the noise calculation modules, which produce the results and return them to the geodatabase for subsequent post processing and results presentation.

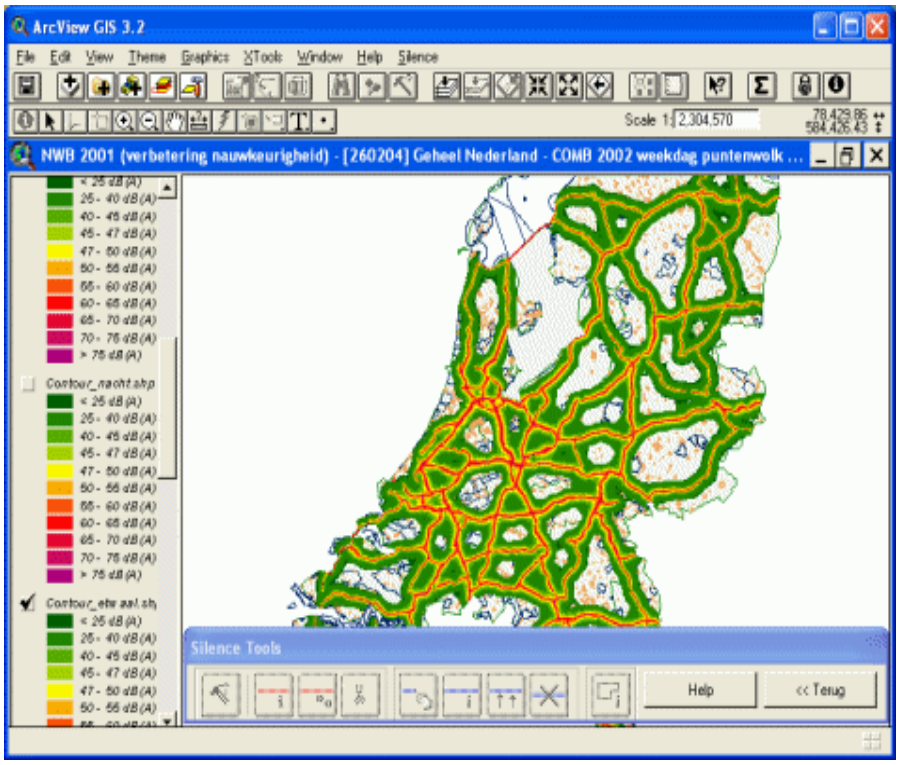

Figure 2: *ArcGIS based Silence 2 by DGMR for the Dutch Ministry of Transport*

7 WHERE DO WE GO FROM HERE?

Environmental noise is created by some of the key assets which underpin the economic development and functions of society in the 21st Century and yet it also negatively affects large sections of our environment and society. It is a politically, scientifically and technically complex subject to understand and manage.

However, to be able to implement effective environmental noise control policies, and to improve and preserve the quality of our environment and health, policy makers must be aware of the complexities associated with information used in assessing environmental noise, and appreciate the actions required to ensure data of sufficient quality is used.

Research programmes must themselves be related to one another and join-up to ensure the input data requirements of large scale environmental noise assessments are clear and that the relationship between mapping results and aspects such as noise annoyance and health effects, as well as the work of other related disciplines such as air quality, are understood. Failure to achieve this may lead to incorrect or unsustainable decisions being made.

Noise mapping software is powerful and clever, it also produces seductive images which look plausible, however the validity of results is controlled by the quality of input data. If the data used is not quality controlled, then the resultant map and subsequent exposure assessment, by default, cannot be guaranteed either.

In order to achieve this end it is critical to join up with other disciplines who, besides sharing a common problem in the cost of capturing detailed data, may well have a key role to play in the implementation of noise control or reduction measures. Shared confidence in the data underpinning the identification and assessment of noise control options will be critical to their successful implementation – both in terms of gaining stakeholder support and in ensuring the decisions are based upon robust science and actually deliver the benefits intended.

The environmental noise community should therefore support and engage thoroughly with those developing SDIs to ensure the requirement of acousticians are taken on board by data capture programmes and that the acoustics community are aware of GI best practice, in terms of both technological approaches and in information management practices.

8 CONCLUSION

Due to the detailed resolution of data typically used within large scale noise maps, it is common for noise maps to be the development driver for links between technical communities working in noise, GI, transport, planning and air quality. Developing noise maps to provide input to the END presents the acoustics community with the possibility of being at the centre of a wide ranging cross-discipline collaboration providing that external initiatives are understood and embraced.

The ultimate aim of living in a world where our environment and health is preserved and protected is a common goal for the environmental noise and geographic information communities. By working together the respective knowledge of both communities will help to enhance our world and ensure the correct data is captured and made available for intelligent joined up decision making. This will further support sustainable environmental, transportation and land use planning.

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