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Equivalence within noise mapping projects

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ABSTRACT

Initial estimates indicate that over 115 million people dwell within major cities across the EU for which noise maps and action plans have been prepared for the 1st round of activities under Directive 2002/49/EC. The results derived from the maps, and the summary action plans, have now largely been submitted to the Commission, and the process of drawing comparisons between cities and Member States is being undertaken. Furthermore DG Environment is currently undertaking a review of implementation of the Directive in preparation of a report on potential amendments to the Directive prior to the 2nd round of activities due to be reported in 2012 and 2013. In this context it is appropriate to review evidence from research and 1st round mapping projects to assess the extent to which it may be possible to undertake meaningful comparisons between exposure results from different agglomerations. Consideration will be given to issues such as the sources of uncertainty within the noise mapping process and assessment of population distribution, the impact of using GPG Toolkits, the modelling decisions open to the users, the equivalence of methods of assessment, and the propagation of uncertainty into the submitted summary results. The "equivalency issue" is addressed, and suggestions presented for future comparisons of noise mapping results, including the necessity for introducing a declaration of the standard modelling uncertainty as a part of the noise mapping results.

1. INTRODUCTION

Directive 2002/49/EC of the European Parliament and of the Council relates to the assessment and management of environmental noise, and is commonly referred to as the Environmental Noise Directive or END[1]. The aim of the Directive is: *"to define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to exposure to environmental noise"*. And to that end three stages are set out:

- Undertake strategic noise mapping to determine exposure to environmental noise;
- Ensure information on environmental noise and its effects is made available to the public;

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- Adopt action plans, based upon the noise-mapping results, with a view to preventing and reducing environmental noise where necessary and particularly where exposure levels can induce harmful effects on human health and to preserving environmental noise quality where it is good.

In 1996 the EC published the Green Paper on Future Noise Policy[2], within the Executive Summary the stated future vision is set out *"a framework based on shared responsibility involving target setting, monitoring of progress and measures to improve the accuracy and standardisation of data"* and *"cooperation across the Community to improve the data situation and the comparability of information"*; whilst paragraph 4.2 suggests that the future Directive provides *"Provisions for the exchange of comparable information on noise exposure between Member States"*.

When the Directive was passed in 2002 it reaffirmed these aims, in the preamble paragraph 5 *"should inter alia provide a basis for developing and completing the existing set of Community measures concerning noise emitted by the major sources, in particular road and rail vehicles and infrastructure, aircraft, outdoor and industrial equipment and mobile machinery, and for developing additional measures, in the short, medium and long term"* and paragraph 7 *"Data about environmental noise levels should therefore be collected, collated or reported in accordance with comparable criteria"*.

To support the stated aims of comparability, Article 6 of the Directive states that *"Common assessment methods for the determination of L_{den} and L_{night} shall be established by the Commission in accordance with the procedure laid down in Article 13(2) through a revision of Annex II. Until these methods are adopted, Member States may use assessment methods adapted in accordance with Annex II and based upon the methods laid down in their own legislation. In such case, they must demonstrate that those methods give equivalent results to the results obtained with the methods set out in paragraph 2.2 of Annex II."*

This clearly sets out the process by which a common assessment method may be introduced into the Directive, and also clearly states that if national methods are used in the interim, they must be demonstrated to provide equivalent results to the EC recommended Interim Methods.

This would appear to raise the two questions. (1) What constitutes an "equivalent result"? (2) How may this equivalence be demonstrated? As we have now witnessed the first round of strategic noise mapping it may also be appropriate to ask a third question, (3) Is the current approach to strategic noise mapping supporting the needs of noise action plans? This paper aims to discuss some of the issues around comparability, equivalence and the chosen means of demonstration via the published JRC protocols along with a brief review of some of the issues which have become apparent during the 2007 noise mapping.

2. END USAGE REQUIREMENTS FOR STRATEGIC NOISE MAPPING

The strategic noise mapping undertaken within the context of the END is charged with meeting the requirements of a number of levels of policy making. Through the principle of subsidiary[3] it is intended that decisions are taken as closely as possible to the citizens, which results in policy being made on several levels, as appropriate, at EU level, national/regional level and local level.

At EU level the results submitted need to *"provide a basis for developing Community measures to reduce noise emitted by major sources"* (Article 1 (2)) and provide the evidence base for an overall health impact assessment over the worst affected areas. This is in line with the fact that the EU owns the majority of legislation controlling noise emissions at source. Some examples are: motor vehicle type approval including pass-by

measurements; motor cycle exhausts; tyre regulations; rail vehicle interoperability; aircraft fleet restrictions. In order to support the development of Community measures, the strategic noise maps should be able to address these particular aspects, and preferably report information to Commission which enables the policies to be shown in action.

At a national or regional level there are a number of other policy aspects which may be applicable. These could include issues such as: vehicle restrictions; tyre restrictions; promotion of electric/hybrid vehicles; promotion of fleet change through scrappage incentives; traffic calming; national rail grinding strategy; national road surfacing policy; airport access charges or action plan policies.

At a local level, the local authorities or municipalities may have a further set of requirements which could include: local actions such as those in the "Silence"[4] handbook; road surface changes; barrier design; local rail grinding or rail vehicle brake changes or rail absorbers or low emission zones.

This list of requirements is arguably largely a product of the first round of strategic noise mapping and noise action planning. Over the past few years the end usage requirements of the strategic noise maps have become clearer as they have been reported to the EU, and used at a national and local level. It is probably reasonable to suggest that many of the national and EU level requirements were not clearly identified prior to the first round of mapping.

3. COMPARABILITY

The END required all Member States (MS) to produce strategic noise maps for the main sources of environmental noise, i.e. major roads, major railways, major airports and agglomerations with a population of more than 250,000 persons in 2007. The majority of these results have now been reported[5], and analysis of the results has begun by the European Environment Agency (EEA)[6] comparing the results between cities and between MSs.

Undertaking analysis on the reported results is a simple task in itself, however the key question is to whether this exercise is based upon a sound premise that the results delivered are comparable, and that the analysis provides valid results. Conversely do the results of the analysis begin to highlight unexpected differences within and between Member States which may suggest underlying problems with the assumption of comparability.

Below we will briefly review some of the aspects of the assessment of noise exposure which need to be consistent between project areas for robust comparability. Many of the issues raised below are discussed within guidance available from WG-AEN GPGv2[7] and Imagine WP1[8], however this guidance is only optional, and covers a wide range of "acceptable" approaches.

A. Basis of Assessment

During the design of the strategic noise mapping projects there are a number of technical and policy decisions taken which will result in a diversification of approaches between assessments. Examples of some of these aspects are discussed.

The Directive requires the population exposure from all noise sources within agglomerations to be assessed. The definition of an agglomeration is not categorically stated rather it is left to individual MS or local public bodies to determine. In some MS the concept of agglomeration is long held, and well defined, in others it is only existent for EU strategic assessments. There are a number of options for the definition of agglomerations, these can include: authority/municipality boundary; LAU2 codes; urban areas; population density criteria; planning areas etc. This can lead to large differences in population density and distribution, along with variation on the inclusion of open spaces. As an example Figure 1 illustrates four options for the definition of the Belfast agglomeration[9], all of which

would be valid within the context of the END, but which would lead to significant statistical bias in the exposure assessment.

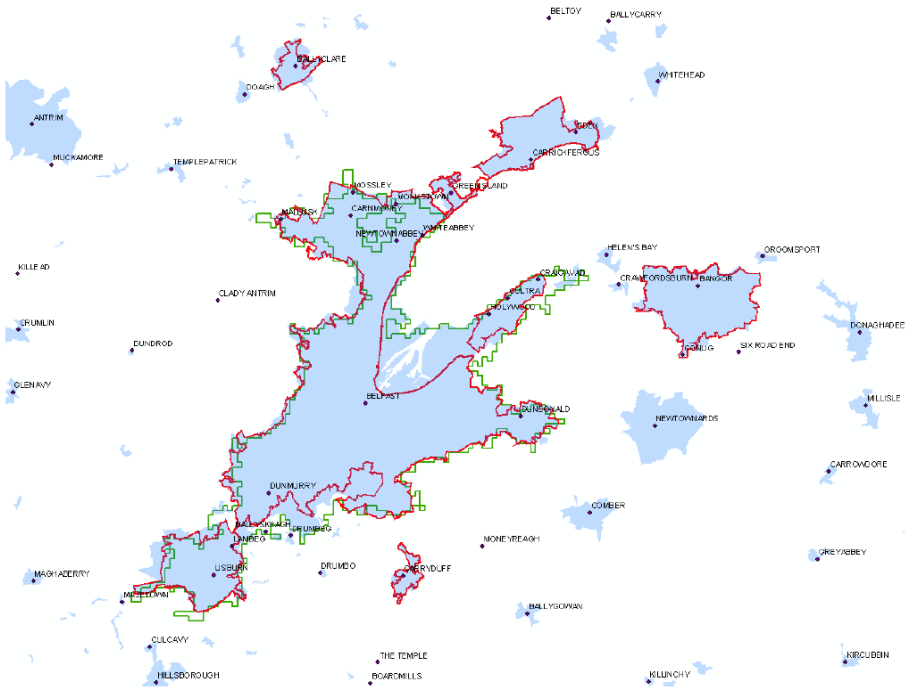

Figure 1: Uncertainty associated with the definition of agglomerations (after Jones, Ispra 2009)

There are similar discussions over the definition and identification of major roads and major railways. Should the identification purely be on the basis of exceedance of the stated flow threshold, or should they first be filtered to exclude roads which do not have some form or road classification or strategic significance? Applying a threshold to sources for which the traffic flow fluctuates around the threshold value will inevitably result in a patchwork of gaps in the major road or major railway network. The use of road classification requires another policy decision in the noise mapping process.

There is also an issue with the assessment of major roads and railways within agglomerations. In some cases the sources are assessed twice, one by the agglomeration competent authority, and once by the national agency. This can lead to conflict and confusion with regard to reporting and public presentation. In other cases the responsibilities split at the agglomeration boundaries, but there will remain differences between assessments which may lead to discontinuity in results at the boundary.

Industrial and port sources are to be modelled within the agglomerations, however aside from the statement in Article 3 (a) of the Directive *"such as those"* covered by IPPC there is no clear statement. This phrase can be used to screen out all non-IPPC sites, which may lead to noise generating industrial activities being omitted, and site emitting little noise being burdened with assessment. Conversely, how else could industrial sites be consistently selected?

For the assessment of aircraft noise there are questions over the selection of airfields, particularly within agglomerations, as well as the definition of "a military movement", however total number of movements are to be assessed for mixed civil/military airfields, and the inclusion, or otherwise, of helicopter movements or heliports.

All these design aspects will lead to difference in assessment between agglomerations across the EU, and possibly even within a MS, and lead to a statistical bias in the results generated when comparing differing outcomes from the same decision.

B. Method of Assessment

The assessment of noise immission has been undertaken across the EU through the use of computer modelling techniques. These models are based upon a standard documented method of assessment, which is translated into a software tool which analyses 3D model data. The basic process in the majority of cases has three stages: a source emission model based upon various parameters, a propagation model to assess the effect of distance and obstacles between the source and the receptor, and finally effects within the locality of the receptor.

There are many factors which influence the quality of the assessment, and the uncertainty in the results which are generated, these include[10]: input data uncertainty; uncertainty propagation or sensitivity; model uncertainty; software uncertainty and population exposure uncertainty. The documented method of assessment is only one aspect of total uncertainty in the assessment, but obviously can challenge comparability.

In advance of the Commission establishing a common method of assessment, the Directive proposes the use of adapted Interim Methods, or allows the use of adapted National Methods, provided that it is demonstrated they deliver *"equivalent results"* (Article 6, 2) to the Interim Methods. This flexibility has led to wide variations between, and even within, MS where methods of assessment are chosen by national authorities, local competent authorities, or even mapping contractors, often on the basis of familiarity. The recent JRC report[11] indicates that seven MS used only the Interim Methods, five used only National Methods, and 15 used a mixture of Interim and National methods depending upon the area or source of assessment.

There are a wide range of reasons for the array of selected methods including: the recommended Interim Methods do not reflect current versions of the national methods they are based upon; XPS 31-133 Interim is not verified; RMR Interim is not verified; the use of Dutch train models outside The Netherlands is challenging; "trust" in national methods due to experience. As to whether any of these methods are able to demonstrate that they produce "equivalent results" to the Interim Methods is presently unknown, although there is a question to be answered as to what the results from the Interim Methods actually are.

In 2003, Wolfel *et. al.* suggested[12] that: *"A suitable software package for strategic noise mapping must provide a robust, coherent and reliable implementation of the interim or national computation method"*. At present the software implementations of the Interim Methods have not proved to be reliable and robust, mainly due to the fact that there is a lack of clarity in the standards, a lack of test cases for verification and a lack of accreditation[13]. The recent JRC report on equivalence provides results for three commercial software packages, running the same models, with the same Interim Methods, by the same user. Analysis of these results across the 1741 receptor locations indicates an average 95% CI of 4.6dB, and a range of 95% CI of 0.2dB to 33.3dB. These results clearly indicate the challenge associated with transposing a documented standard into a software tool in the absence of relevant test cases and validation protocols. This issue is further explored in the authors accompanying paper[14].

C. Execution of Assessment

Undertaking the assessment of noise levels requires a wide array of input datasets to cover the source characteristics and the 3D propagation environment. The WG-AEN GPGv2 provides extensive advise on the potential impact on the quality of the results when using less than optimal input data. These recommendations are backed by the results of two extensive research projects which undertook error propagation testing of the

Interim Methods and UK National Methods for road and railway noise assessment.[15,16] Guidance is also available in the final report from IMAGINE WP1[8].

The availability of input data, and the concatenation or simplification of data during the construction of the noise model can introduce uncertainties of 3 to 5dB 95% CI in many common situations. One example is the issue of roads without known traffic flows. Within agglomerations the END can be interpreted in such a way that it is required to model road traffic flows on all roads within the agglomeration. This view is supported within WG-AEN GPGv2, and Toolkit 4.5 sets out some example values for default traffic flows which could be assigned to these road links. It is widely agreed that we will never have traffic data for all the roads within a city, and that in many cases the minor roads without known flows may account for 80 to 90% of the total road length, even if it is a much smaller proportion of the total traffic volume. Figure 2 illustrates an example of a noise model assessed with and without the use of default traffic flows. Both approaches are currently in line with the END, however there is an uncertainty of 8.8dB 95% CI between the two sets of results, with individual receptor points changing by up to 11.7dBL_{den}. Until there is a more uniform approach to data issues such as this, the comparability of model results is to be questioned.

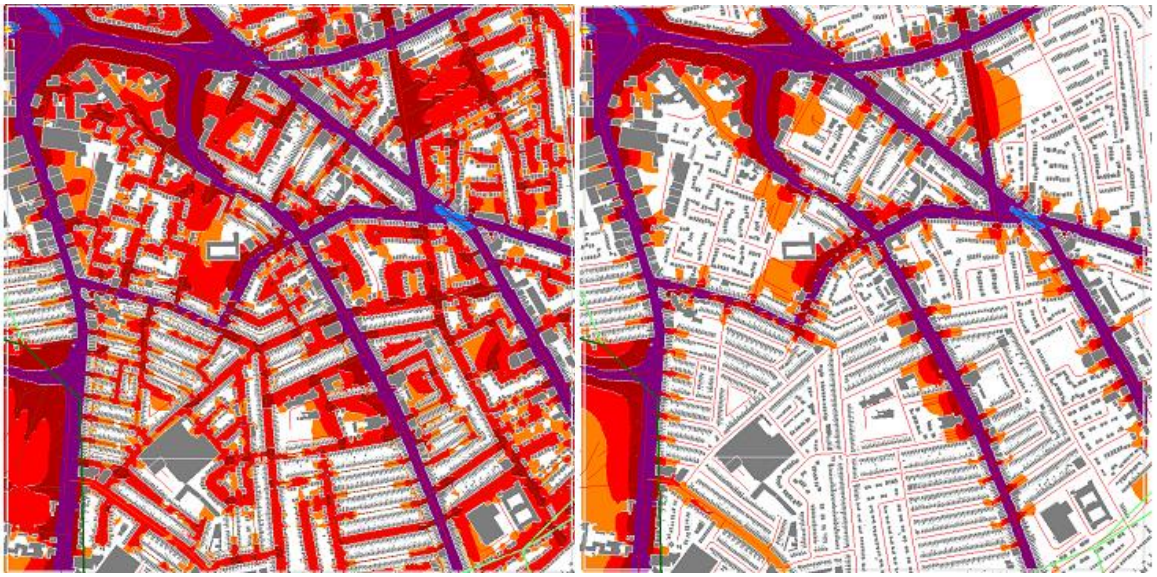

Figure 2: Uncertainty associated with the default traffic flows

A further aspect of the assessment which has the potential to introduce uncertainty into the results is the use of calculation settings within the software tools. Modern noise mapping software tools contain many advanced features which the user may enable to provide an increase in calculation speed. Many of these are commercial differentiators in the market, hence they tend not to be clearly described or full explained, and there is a lack of clarity of knowledge amongst the users as to the impact on the calculation quality which results from the reduction in calculation time. One universal feature is the “source search radius” where the software ignores sources outside the source radius set by the user. In many historic project this has been set in the region of 2,000 to 3,000m to ensure that none of the relevant emitters are ignored. In projects where time and budget constraints have taken precedence, the authors have witnessed this being reduced to 1,000m or even 500m. This brings large reductions in calculation time, but also introduces non-linearity and systematic bias into the results, as emitters are arbitrarily omitted solely based upon distance from the receptor, rather than on potential influence. Figure 3

provides an illustration of a difference map where the source search radius is reduced from 2,000m to 500m. Whilst many locations adjacent to roads can be seen to be within 0.5dBL_{den}, there are extensive areas where the difference is between 5 and 10dBL_{den}. Overall the reduction in search radius may have reduced the calculation time by 97%, however it also introduced an uncertainty of 4.2dB 95% CI, with individual receptor points changing by up to 10.7dBL_{den}.

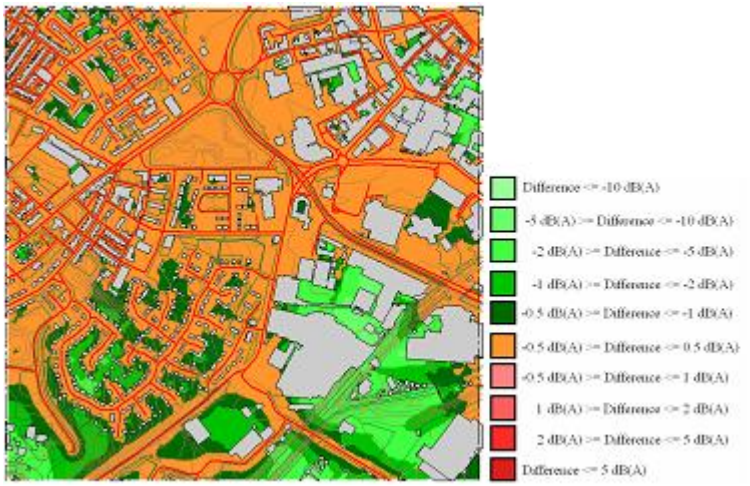

Figure 3: Uncertainty associated with the user calculation settings

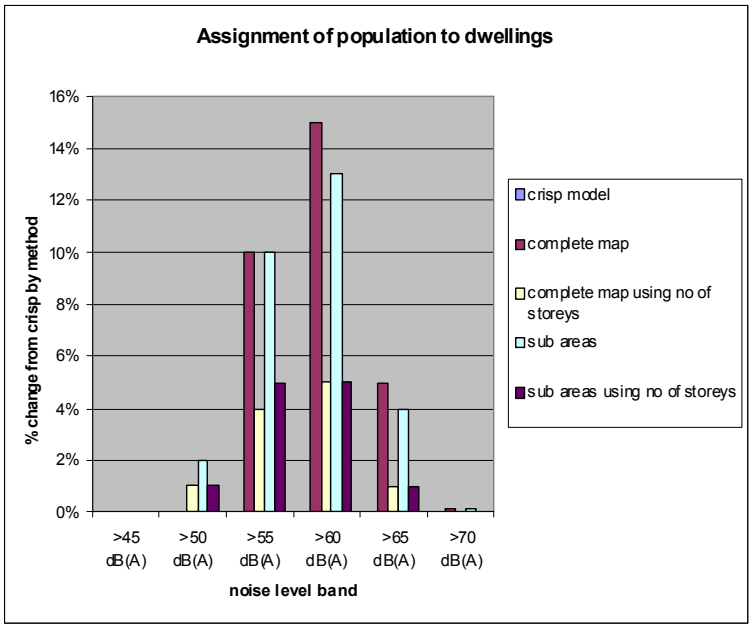

Figure 4: Uncertainty associated with methods of assigning population to dwellings

D. Exposure Assessment

Following the assessment of noise levels, an assessment of numbers of dwellings and population exposure is undertaken. As there are very few cities where dwelling level population numbers are available, it is generally required to use less detailed information and estimate the number of people per dwelling from this, often using additional secondary

datasets, such as post codes or postal delivery points, to support this process of estimation.

The Final Report from IMAGINE WP1[8] sets out a number of case studies illustrating methods of determining dwelling level population values from lower resolution start points, and provides an estimate of the relative accuracy of each approach. Defra research project NANR 93 also investigated the assignment of population to dwellings and presented the results statistically. Figure 4 illustrates the percentage change in population exposure statistics per noise band based upon a different means of assessing population per dwelling. The illustrated change is relative to the crisp model where actual data was available for people per dwelling. As can be seen the change in exposure is not a smooth shift from one noise band to another, nor is it similar regardless of the means by which the population distribution dataset was developed, rather the different approaches introduce statistical bias into the assessment, and thus do not average out to a similar result or provide comparable statistics.

4. REPORTING OF RESULTS

Annex VI of the Directive sets out the data to be sent to the Commission. In order to support the analysis work of the EEA, and provide for a uniform and consistent style and content of data reported back to the Commission, the ENDRM 2007 Reporting Mechanism was developed. This provides MS Excel format templates for reporting the various data flows associated with the Directive over the first two rounds.

The ENDRM only requests the information which is legally mandated within the Directive. As such the only maps described are for major sources where the 55 and 65dB L_{den} contours are to be presented. The ENDRM asks for these as picture maps within the Supplementary Reports. The main content of the results to be submitted are statistical tables of results for population, dwelling and area exposures. The END does not provide a basis for requiring the reporting of electronic noise contour or grid datasets, nor does it set out a requirement to report the means by which the results were developed, or any description regarding the issues, problems or uncertainties within the process. As such the EC is provided with a large collection of statistics, but no means to assess quality or comparability.

Figure 5 illustrates the type of analysis which may be undertaken with the results submitted to the Commission. It presents the percentage of population exposed per noise band, with one bar per agglomeration. It actually serves as a strong illustration of the issues discussed above, and evidence to support a more uniform approach to strategic noise mapping in the second round. The collection of cities towards the left of the figure are from one highly industrialised MS, which appears to be about the quietest country in Europe, whilst the block near the centre is from another MS which appears to be the noisiest country. The actual exposure of the populations is likely to be far more similar than indicated, however significant difference in the means by which the assessments have been undertaken have lead to large difference in results. It should also be noted that towards the right there is a city where greater than 100% of the population is exposed to noise above 55dBL_{den}. This is obviously a statistical error but should not be unexpected as the reporting of agglomerations to be mapped, and their populations, was in DF1, June 2005, whereas the mapping results are in DF4, December 2007.

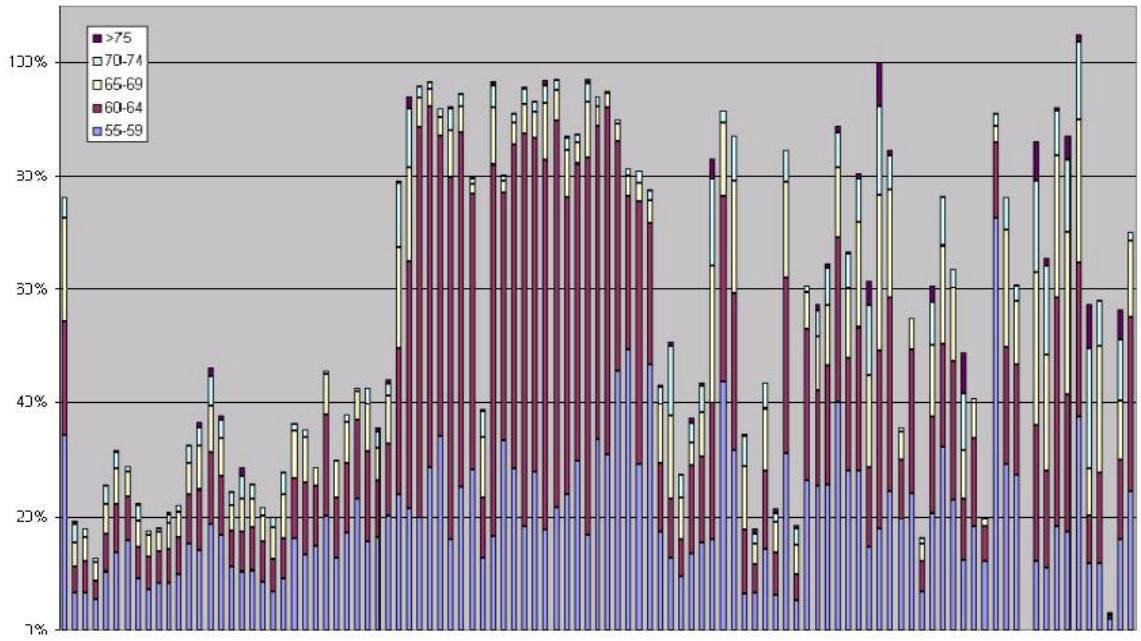

Figure 5: Percentage of population exposed to noise within EU agglomerations (after Jones, Ispra 2009)

5. CONCLUSIONS

With the first round of activities under the END drawing to a close it is possible to begin reviewing the process and outcomes from the actions undertaken to develop strategic noise maps and action plans. There are many reports and presentations from city authorities and regional municipalities across the EU which present a picture of the process working and begin to show results. Arguably these have been most successful where there is local political will, and the local administration have taken control of the mapping and action planning process in order to deliver local results.

When reviewing the process form a national or EU level it is challenging to take such a positive view. From the first round of noise mapping, we have noise exposure data which is based on: different definitions of agglomerations; different 'relevant year'; noise source data of varying quality and extent; geographical and topographical data of varying quality; varying availability of meteorological data; different noise calculation methods; different software implementations of the individual noise calculation methods; different software settings; demographic data of varying quality; and different methods of assigning noise levels to buildings. The results may provide for a first estimate of the exposure and the extent of the problem; however they are not considered a sound basis for comparability.

Furthermore, if one reviews the requirements set out above, and compares them with the information actually delivered back to the authorities at national or EU level, it is apparent that comparability within MS is a challenge, but at EU level it is almost without purpose. Allied to this, it is apparent that the information reported up the chain does not provide the detail or the focus which enables the development of, or progress reporting on, strategic policy making on environmental noise management.

4. FUTURE NEEDS

If one begins from the premise that the work undertaken under the Directive should support the aims and objectives of the Directive, and provide an evidence base for local,

national and EU level policy development, then a greater degree of uniformity, comparability and equivalence needs to introduced into the assessments.

In order to provide a more comparable set of results, and an evidence base fit for the purpose of policy development, some of the steps which could be introduced include: common definition of agglomerations; common methods of assessment; common approach to data shortages, including guidance; assessment and reporting on impact of data shortages on uncertainty; verification and testing of software tools, including guidance on use of settings and assessment of uncertainty; and clearer guidance on population exposure assessment.

Should the Commission determine to amend Annex II and introduce a common assessment method, it must be realised that an array of supporting guidance documents will be required if comparable results are to be achieved.

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