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On Noise Mapping and Noise Action Plans for Large Urban Areas

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Noise has increased in European cities, owing to the growing urban development in the past decades. Management and reduction of urban noise have become necessary.
Noise community ordinances were approved at national and local levels in various countries. They usually establish noise limits for various activities and zones, according to the land use, and define the basis of noise abatement strategies. The European Directive 2002/49/EC requires drawing of noise maps and noise action plans in agglomeration with more than 100,000 inhabitants and in areas around large transport infra-structures.
The solutions for noise reduction are usually well known. However, their application in large urban areas is not straightforward. The phasing of the plan has to consider that while the benefits of some solutions can be achieved in the short-term, some will only become apparent in the medium and/or in the long-term.
The noise action plan must be based on strategies that take into account a vast number of technical, operational, and economical factors. The cost-benefit ratios of all solutions have to be considered. The citizens must also be involved in the process.
A discussion will be presented on all these issues.
Results of recent studies for the cities of Lisbon and Almada as well as other suburban areas will be presented. The results will be discussed on the basis of new findings on urban soundscaping and on the correlation between the results on the noise maps and the perception of noise by the urban populations.

1 Introduction

Noise is being recognised as a serious environmental problem, and one which must be accounted for in a sustained development policy, which is designed to improve the quality of life for citizens. European cities have developed in the recent past mostly around their historic centres. The fast social and economical growth in the 20th century was not always accompanied by adequate land planning and environment management measures. Cities in Europe have grown by 20% in size and their population has increased by 6% in the past 20 years. The need for more efficient transportation meant an increase in the means of transportation and on the number of vehicles. As a consequence, cities face increasing noise levels. However, a growing acknowledgement of the citizens to their rights to a good (less noisy) environment has called for actions to manage and to reduce noise in cities.
The European Directive 2002/49/EC of 25 June 2002 relating to the assessment and management of environmental noise [1] defines the basic principles of a harmonised European noise policy, following the publication of the European Commission Green Paper on the Future Noise Policy in 1996 (COM(96)540).
Community noise ordinances have been promulgated by local and by national authorities in many countries establishing noise zones and noise limits and defining the responsible bodies and obligations to reduce noise. In Portugal, the Noise Pollution Act of 2000 [2] requires the local authorities to draw noise maps and noise action plans.

Noise maps describe spatial distributions of noise levels. They allow an efficient visualization of the noise distributions in areas where the land uses are sensitive to noise. Noise mapping is a very efficient noise assessment method in an urban area. For large cities, challenges have to be met in terms of data management, data reduction, calculation methods, optimization procedures, validation techniques and presentation of results so that the maps can be powerful tools to be used for urban noise planning and design.
Noise in cities is contributed by many sources and is part of the urban soundscape. Urban noise must be managed and controlled so that excessive noise levels do not conflict with common human activities and with the people's perception of wellbeing.

2 The European Environmental Noise Policy

The European Directive 2002/49/EC was prepared and published in order to address noise issues. In the long-term, it aims to reduce the number of people exposed to noise and to achieve a better quality of the acoustical environment. It requires the competent authorities to draw noise maps, to inform the public about noise exposure and to draw up action plans. This Directive also defines a new noise indicator, Lden, which is a 24 hour noise index to be used by the member states in all noise maps and action plans.

The Environmental Noise Directive defines the basic principles of a harmonised European noise policy. They include the assessment of the environmental noise, both overall and from major noise sources, such as transportation and industry, the number of people exposed to different noise levels, action plans for reduction of noise exposure, communication with the public, and communication between the European Commission and the Member States. A database will be set-up in the future with information from all the EU member states.

Strategic noise mapping and action plans are required in that Directive for the assessment of noise from major transport infra-structures and in communities with more than 100,000 inhabitants. Two phases are defined. The first one regards all agglomerations with more than 250,000 inhabitants, all major airports with more than 50,000 movements per year, all major roads with more than 6,000,000 vehicles per year and all railways with more than 60,000 passages per year. The second one corresponds to all agglomerations with more than 100,000 inhabitants, all major roads with more than 3,000,000 vehicles per year and all railways with more than 30,000 passages per year.

Strategic noise maps for the first phase must be finished by 30 June 2007. Action plans must be completed by 18 July 2008. For the second phase, all maps must be presented by 30 June 2012 and the corresponding action plans by 18 July 2013. They must all be reviewed every five years

The Annexes of the Directive define the minimum technical requirements for the noise maps and for the action plans. They concern the contents of the maps, the format and presentation of the results, the estimated number of people located in areas exposed to noise and further information that should be given together with the maps as well as the data that is required to be sent to the European Commission.

Some national ordinances, such as the Portuguese Noise Pollution Act [2], approved in the year 2000, require the local authorities to draw strategic noise maps for preparing or reviewing their Land Use Plans. Action plans are required to manage noise issues and effects, including noise reduction, if necessary. They are part of the long-term strategies to reduce the number of people affected by noise.

Noise management and reduction plans must be based on a general strategy for the management of the urban areas, considering the land uses, the means of transportation and the dynamic development of the city. The legal framework, both at local and at national levels, is important as its enforcement is.

3 Noise Mapping

Method

Noise maps can be drawn from measurement or from calculation. Measurements lead to a static map with overall values. Contributions from the different component noise sources are not easily identifiable. Representative long term measurement surveys are difficult and expensive tasks and the technical means required can be extensive. Calculations, on the other hand, produce data bases that allow easy updates and can distinguish each separate contribution from all other component noise sources. Nevertheless, considerable computer power and memory may be required for large cities, due to the vast amount of data and large number of calculations, though this might not be a real problem with today's computer technology. Accurate and comprehensive data is, however, required and reliable and efficient emission and propagation calculation methods are called for. Although measurement based maps have been used until the early 90's for noise mapping, calculation methods are now widely used for noise mapping in most cities in Portugal as in other countries.

A geographical 3-D model is created for the area under assessment. All information regarding the land, all objects (buildings, walls, bridges) and noise sources (roads, railways, airports, industries) with heights is included. GIS data is usually used. This model is validated by using visual inspection techniques (images and videos).

The noise map is a layer of information which is superimposed on the geographical information, following emission and propagation calculations for each noise source, road, railway, air traffic, industry, construction, leisure activities, and at each point. Calculations are performed in the points of a grid where the dimensions usually vary between 5 m and 30 m in a city, depending on the complexity of the area, the density of occupation or the purposes of the map.

For each noise source, a corresponding data base is built up containing emission data (traffic density, vehicles or aircraft, equipment, industry lay-out, noise levels, octave band spectra, for example), propagation data (road pavement, rail, ground surface, acoustic properties of building façades for example), meteorological data and other data relevant to establish the magnitude of the noise levels in each assessment location.

Graphic noise maps are the most interesting ones. They can be drawn as noise curves or noise zones corresponding to 5 dB intervals. Appropriate colour or grey codes must be used. ISO 1996 Standard [3] recommends a suitable colour code.

Noise maps are produced for the different reference periods. The Portuguese legislation [2] now establishes two periods: day (07h00-22h00) and night (22h00-07h00). The European Directive 2002/49/EC requires three periods: day, evening and night with limits to be defined by each country.

Noise maps were drawn for the cities of Lisbon, Almada, Loures and Albufeira. The first three are communities with more than 250,000 inhabitants each. Albufeira is much smaller but it features some peculiarities since it is the centre of the Algarve tourist area, with two different realities found in the two yearly seasons (Summer / Winter). Maps were drawn for the A-weighted equivalent continuous sound level LAeq in each reference period. All maps were validated following a comparison procedure between calculations and measurements carried out during the two reference periods in a number of places randomly selected. Results were found to differ within 2-3 dB, well in agreement with the recommendations of the EU WG3 “Computation and Measurement” [4]

Figure 1 shows a sample of the strategic noise map of the community of Loures, in Portugal.

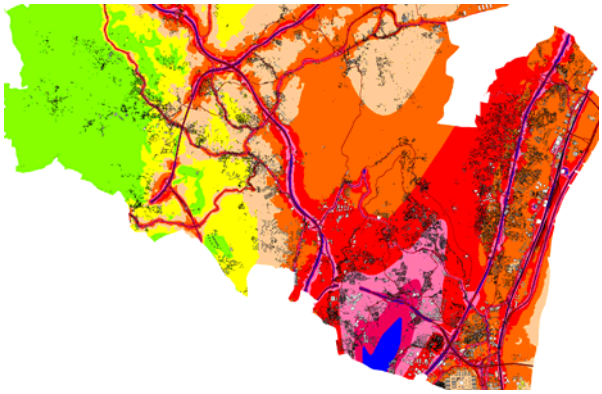

Figure 1 - *Sample of the strategic noise map of Loures*

Major noise sources can be identified as air traffic (an airport is located nearby), railway lines and major roads. Some urban centres and some undeveloped land can be identified.

Figure 2 shows an extract of a noise map of another large urban area, Almada.

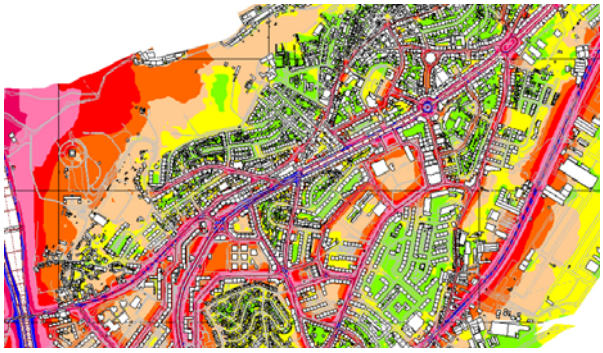

Figure 2 - *Extract of the detailed noise map of Almada*

This is a detailed noise map, containing much more information than a strategic noise map. Virtually all roads and railway lines are considered as contributing noise sources. Noise from industrial units and noisy leisure areas is also included.

This type of map, with all information concerning noise sources, transport infra-structures, industries, dwellings and population is necessary and a precious tool for management of urban noise and for urban development purposes.

The noise maps also followed the Noise Mapping Guidelines issued by the Portuguese Environment Institute [5], which define basic procedures for noise assessment and calculation and for the production of noise maps to integrate the Land Use Plans. The “Good Practice guide for noise mapping and production of data on noise exposure” [6] prepared by the EU Noise Policy Working Group on Assessment of Exposure to Noise (WG-AEN) and published by the European Commission in December 2003 addresses a vast number of issues and problems usually encountered on noise mapping regarding data management and noise calculation. Version 2 is currently being finished and publication is expected for late 2005.

Discussion

Basic requirements for noise mapping of large urban areas represent considerable technical challenges: vast amounts of data, enormous computer power and computer memory, reliable data reduction procedures and criteria for decisions on which noise source to include. Problems may also be found on interaction between the results and other type of data owing to the large file sizes or the complexity of shape files. Data is not always available as necessary. Digital 3-D land data is now almost widely available in all municipalities in Portugal. They are usually integrated in GIS allowing the crossing of acoustical data with other types of data, such as population, for example.

Noise source data is usually a problem. Road traffic data is not commonly available for all roads with the quality (types of vehicles, time representativeness, and accuracy) and quantity (different road segments)

required. The maps described here required that a large number of traffic counts were performed both by the municipalities and by our technical team. Air traffic data was obtained from the airport authorities based on radar data and pre-defined air paths and routes. Railway data included results from a large program of measurements of noise emissions of rail equipment and from a prediction program FERR+ developed by the CAPS-IST Acoustics Group in recent years. Noise emission data from industry, leisure or other similar areas was obtained from measurement. The surveys were carried out in different times of the year, as necessary, to account for seasonal differences.

All air and railway traffic contributions were included in the maps. Roads with less than 6.000.000 vehicle passages per year were not included in the strategic maps. This number was set to 350.000 vehicle passages per year for the detailed maps. This criterion was seen to be the most adequate for the production and use of results.

Inclusion of industrial sites was usually decided upon onsite observations and objective analysis of the noise emissions levels. Emission data was obtained from measurements.

Meteorological data was considered whenever found to be a relevant factor. Temperature and humidity gradients are not usually significant in the studied urban areas but wind regimes can be.

Accuracy of all data was generally checked in all phases of each mapping project.

Noise maps are very powerful tools for communicating results of assessment of environmental noise to the general public and also for technicians to devise noise correction measures and to study alternative urban scenarios.

A more recent line of the work on large cities at CAPS-IST concentrates on the “quality” of the sound environment. Quality noise maps are being developed by using human perception as part of the assessment procedure. The promising results aim to contribute to the management of the soundscape in large urban areas [7-8].

4 Noise Action Plans

Action plans find their most complex application in city areas. Solutions can be of various types: technical, planning, behavioural and educational. The latest are very important on the raising of the awareness of citizens to noise and to noise effects and on the reduction of noise emissions in many circumstances.

Technical solutions are to be applied in urban areas with the utmost care so as not to affect the rhythm of life and the socio-economic texture of the city. The actions should also be easily accepted by the populations.

Since transport infra-structures can be recognised as major sources of noise, technical actions on the transport systems can produce interesting results. Alternative scenarios can be studied by using noise maps as prediction tools by optimizing the incorporation of different noise reduction measures and solutions.

Such measures can be of various types. They can include changes in road or railway profiles, low noise pavements (porous or porous-elastic) type, reductions, limitations or restrictions on traffic (types of vehicles, speed, hours of access, for example). Some traffic limitations must be introduced very carefully and in a gradual fashion so as not to be met with the inhabitants’ opposition since they may be perceived to limit economical activities, to limit mobility or to affect real estate value. Transportation and land planning (private versus public transportation, bus lanes, parking areas, shuttle buses, and pedestrian areas) are important components of the plan. Some types of noise control devices, such as acoustical barriers, may be used in suburban highways but should be avoided within city areas, as they could create problems of other nature (visual impacts, light blocking, wind redirection, for example).

Since noise also results from the citizen’s behaviour (driver, for example), information and education campaigns usually produce good results. These should be aimed at all types of people. School campaigns will produce results in the long term. Information on the different actions and on the results should be well disseminated and should correspond to the general aims of the action plans.

Costs of some actions can be high and have to be scheduled and linked to the achievement of results. The whole plan has to recognise that while some benefits can be obtained in the short-term, others will only become apparent in the medium and/or in the long-term.

Noise maps are used as tools for identification of the areas to be protected and for the assessment of the results. They are also excellent means of communication of results both for technicians and for the public.

Figure 3 shows an example of an area of the city of Lisbon where an Action Plan was drawn.

The area comprises residential buildings, commercial areas, offices and deactivated industrial buildings. The area is being redeveloped by introducing new dwellings and office buildings and a considerable improvement of the environmental conditions was expected. The plan included a redefinition of the land uses in some areas, recommendations on the

architecture of the new buildings and changes on the profile of the major roads by lowering the height of the existing roads. Low noise pavements were introduced in the primary and in the secondary road network where speeds are higher. Some traffic restrictions (low speed) were selectively introduced. Care was taken so that the solutions would not interfere with the operation and functionality of the different built areas and uses and would not change too quickly or too dramatically the access to the area or its atmosphere.

Figure 3 - *Extracts of noise maps of an urban area, (a) before (b) after actions for noise reduction*

The results show a measurable gain leading to an increase in the quality of the acoustical environment of the area.

Figure 4 shows an example of a suburban area where an action plan was devised for.

A school area located close to a high traffic road can be observed, where noise levels were too high, exceeding 55 or even 60 dB(A) on the building façades and in the playground. The plan comprised new sound absorbing porous road pavements and the installation of acoustical barriers on the facing sides of the roads. The solutions were optimized in terms of benefit and of cost.

The results show that considerable noise attenuation values can be predicted and that the resulting noise levels fall within acceptable intervals for educational purposes.

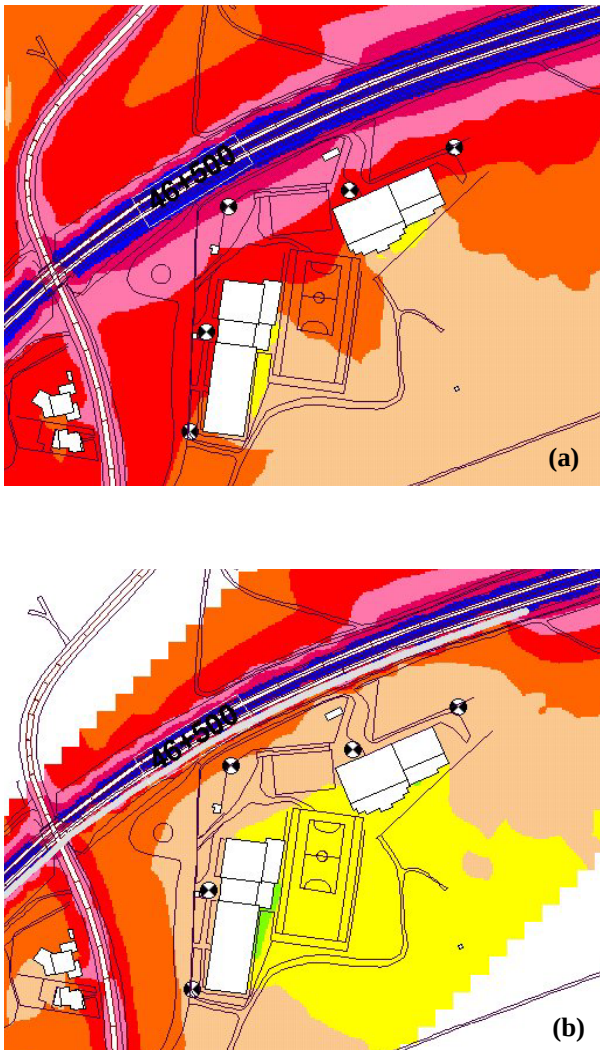

Figure 4 - *Extracts of noise maps of a school area near a highway, (a) before (b) after noise reduction actions*

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References

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[2] Noise Pollution Act, Decree-Law 292/2000 of 14 November 2000.

[3] International Organization for Standardization, ISO 1996. Acoustics – Description and measurement of environmental noise.

[4] EU Noise Policy Working Group 3 "Computation and Measurement" Progress Report June 2001.

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[7] M. Boubezari and J. L. Bento Coelho, "Towards Qualitative Sound Maps with Differentiated Sources", Proc. ICA 2004, The 18th International Congress on Acoustics, April 2004, Kyoto, Japan, I-595-596.

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