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NOISE MAPS FOR ENVIRONMENTAL SOUND MANAGEMENT AND PLANNING

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ABSTRACT

The European Environmental Noise Directive of 2002 (END) requires all large agglomerations and transport infrastructures to draw noise maps and action plans. Noise maps are essential tools for assessing the exposure of the populations to noise as required by END and also for devising noise abatement measures, for planning purposes, and for communicating with the citizens and other stakeholders. The quality of the acoustic environment especially in urban settings results not only from reducing and controlling noise but also from adequate planning and configuration of the soundscape in the different areas used by the people. Noise maps drawn at strategic and at detailed levels, in quantitative and qualitative formats, are powerful tools when used in strategies aimed at improving the sound quality perceived by the citizens. These objectives have called for innovative procedures and for the development of new or alternative modeling and mapping techniques in the framework of integrated environment management policies. Case studies are presented and discussed.

INTRODUCTION

Noise from transportation can be a problem when it becomes excessive, hindering the population's quality of life. All means of transportation can be serious noise sources, with road traffic playing a major role. In cities this is a key issue. A large gathering of people will produce a number of noise sources that may cause annoyance, especially regarding more sensitive activities, such as sleeping, resting, or learning. Mobility management must integrate with acoustical environment policies in a city with ambitions of a sustainable development.

Local and national governments are then called to set up policies for noise management and control and to devise and enforce strategies for noise abatement and control.

The Portuguese Noise Act of 2000, updated in 2007 [1] requires all cities and transport authorities to draw noise maps and to prepare noise reduction plans where needed. Large agglomerations and transport infrastructures are required to follow the European Noise Directive (END) 2002/49/EC of 25 June 2002 relating to the assessment and management of environmental noise [2] and its more complete set of requirements.

The Group of Acoustics and Noise Control at Instituto Superior Técnico (IST), University of Lisbon, has been working on large scale noise mapping and on action plans of large cities and of all transport infrastructures since the early 1990's. The first noise maps for the Lisbon airport were completed in 1993. The city of Lisbon large scale noise map was started in the mid 1990's and was finished by the year 2000.

Calculation methods were also developed for all types of traffic, some being adopted by the national transport authorities. Since, however, these were not fit for mapping the END recommended interim methods were followed as from 2006 when the END was transposed, except for railway noise where alternative methods were allowed. For railway noise, a thorough study of the national rolling stock was conducted in order to investigate the possibility of accommodating the use of the END interim calculation method RMR96/SRMII.

NOISE MAPPING

Strategic Noise Maps

The Group of Acoustics and Noise Control at Instituto Superior Técnico (IST), University of Lisbon, have been drawing strategic noise maps for the Portuguese local and transport authorities to assess the influence of the major noise sources on the overall acoustic environment and to evaluate the population exposure to noise, fulfilling both national and END requirements [1-2].

Figures 1 shows the strategic noise maps for the L_{den} indicator for the cities of Funchal and Albufeira.

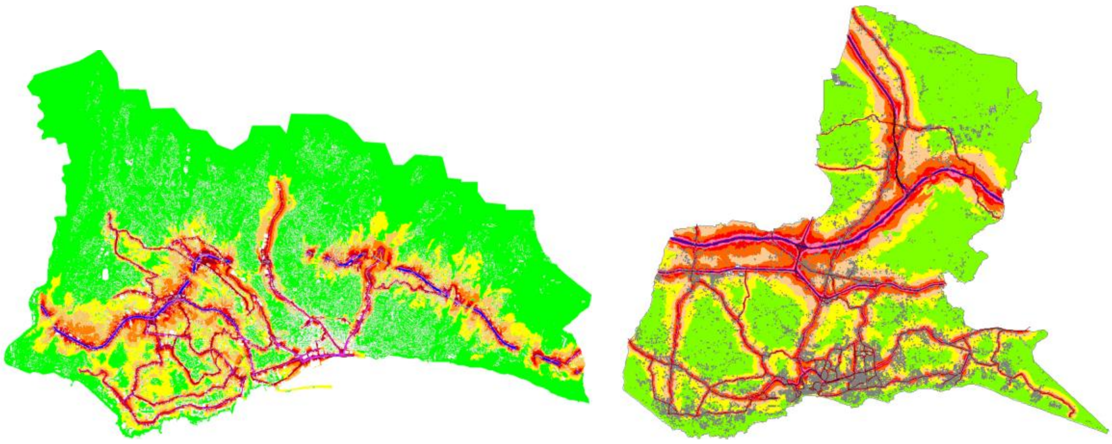

Figure 1. L_{den} strategic noise maps for the cities of Funchal (left) and Albufeira (right)

The strategic maps represent a level of information which is quite important for the definition of acoustic environment quality policies by the responsible bodies, city councils and transport authorities. They are instrumental at the macroscopic assessment stage and for the management of noise issues by planners and acousticians.

Noise maps are also efficient tools for communication with the population and with decision makers. Most Portuguese city councils have made the noise maps available online and some cities provide extracts of the maps with values for the noise indicators (L_{den} and L_n) at the point or building specified by the user.

The END recommended interim calculation methods have been adopted as from 2006 when the END was transposed, except for railway noise where alternative methods could be used. However, a thorough study of Portuguese trains was carried out so that the END recommended RMR could be adequately used.

Railway Noise Modeling

The general use of the Dutch RMR method recommended in the END as an interim calculation method for those countries where a national method was not available has proved difficult, since the railway vehicles are usually quite different from country to country and the RMR method includes a very specific database with a limited number of vehicle classes corresponding to the Dutch trains, though new classes can be added. Nevertheless, since the RMR propagation algorithm is quite flexible, allowing for a vast number of corrections and adjustments to account for the different acoustical effects found in real situations, a thorough study was carried out in order to make the use of the method feasible. The vast database of emission reference values for all types of vehicles under different conditions of speed and number of wagons was used together with results of new measurements.

Pass-by sound pressure levels and 1/3 octave band spectra for each type of train vehicle running at different speeds were measured. An averaging technique was followed, by using samples for different passages of the same type of vehicles, under similar conditions. The 1/3 octave band reference spectra for the different vehicle classes in the RMR database were drawn, for the same conditions. These curves were calibrated for the measured overall noise values.

A curve fitting procedure was then followed to find the curve (train class) that best fitted the measured one. This curve fitting procedure was adopted for all types of trains and conditions, to determine the reference emission values. Corrections were made for track types, namely long welded or with joints, and conditions, such as rail roughness.

Figure 2 shows the measured 1/3 octave spectrum curve for a type of intercity train, together with those of different RMR classes.

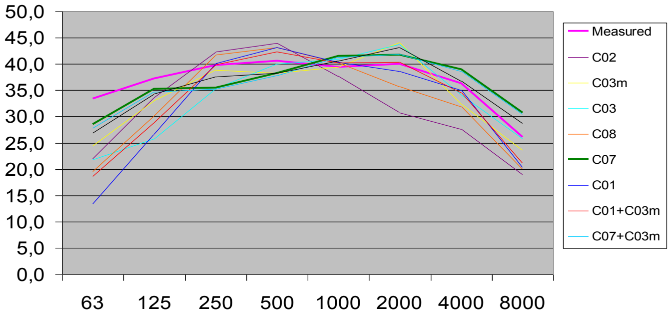

Figure 2. Curve fitting for a type of intercity train

An equivalence table (see Table 1) was then drawn between the Portuguese rolling stock and the RMR database train classes with corresponding corrections making the method possible.

Table 1 – Equivalence between Portuguese rolling stock and RMR database train classes

Rolling Stock	n. units	Category RMR96/SRMII	Factor rolling stock unit / cat. RMR96/SRMII unit	Units of RMR96/SRMII category per trainset
UQE 3150	3	C02	1,14	3,4
UQE 3250	4	C02	1,14	4,6
UQE 2300/UQE 2400	4	C02	3,13	12,5
UQE 3500	4	C08	3,65	14,6
UTE 2240	3	C03	1,00	3,0
UDD 450	1	C05(diesel)	1,00	1,0
	1	C06	1,00	1,0
CPA 4000	2	C09(railcar)	1,00	2,0
	4	C09(carriage)	1,00	4,0
UQE 3400	4	C08	1,00	4,0
UTD 600	3	C05(diesel)	2,00	6,0
LOC5600/2600	1	C03(motor)	1,00	1,0
LOC1930/1960	1	C05(diesel)	1,00	1,0
Corail/Sorefame carriage	1	C01	2,50	2,5
Freight wagon (10m)	1	C04	1,00	1,0

A validation procedure showed typical average deviations to be below 2 dB [3-5]. The adjusted RMR calculation method was then used subsequently for railway noise mapping.

Strategic vs. Detailed Noise Mapping

Noise abatement studies, developed at the action planning level, usually require more detailed information than that provided by strategic noise maps. Urban noise management in general also requires information which usually is not included at the strategic level. This calls for a more detailed mapping exercise, with most streets in the urban area being included in the database together with more detailed data on the noise sources.

Figure 3 compares samples of the strategic and of the detailed noise maps for the central area in the city of Almada. This includes the old city quarters and the downtown area where services and commerce as well as residential areas can be found.

Figure 3. Samples of the strategic noise map (left) and of the detailed noise map (right) of Almada central region

Most differences regard the densities of road traffic. For the strategic noise map calculations, only roads with at least three million vehicle passages a year were considered, according to the END criteria. For the detailed map in the figure, traffic flow densities as low as 350,000 vehicle passages a year were included in the database. For some other cities, a figure of 550,000 passages a year was considered, depending on the local relevance of the low traffic or on the other parameters determining the resulting traffic noise.

The detailed maps allow an insight into virtually every street and building in the city center and those areas where urban sound management is called for. Not only noise mitigation measures can be designed for each place but communication with people becomes easier since it is an interesting visual tool yielding much more understandable results than sound level numbers.

ACTION PLANS AND NOISE MANAGEMENT

Noise maps for management purposes

Action plans have been drawn for agglomerations and for transport infrastructures that fall into the END categories. The Portuguese legislation [1] further requires that noise mitigation plans are drawn for all cities and transport infrastructures where the population is exposed to noise levels that exceed specified limit values. These depend both on the land use and on its sensitivity to noise. The plans aim at reducing noise where necessary and possible, at controlling existing and future sources of noise, and at protecting areas where the acoustic quality is good, for a sustainable development.

The noise and the soundscape in particular in each place must be effectively related to the human activities and to the people's expectations if a good acoustical quality is to be achieved. Our perception of the acoustic environment depends largely on the characteristics of the place but also on our activities during the different periods of the day and on how we expect it to conform to our notion of quality of life.

In cities, the land uses in the whole municipal area were extensively surveyed and the correlation with sensitivity to noise was studied. Noise sensitivity maps were then drawn for the whole municipal area based on the existing land uses [6].

This procedure led to the definition of municipal acoustic zones, each one having distinctive noise limits assigned, according to the national regulations [6]. By correlating the noise zone maps with the noise maps, conflict maps were drawn and analyzed. Noise mitigation measures were then considered where necessary, by taking into consideration cost-benefit ratios, feasibility and practical issues, and acceptance by the populations.

Noise maps were helpful at both the noise abatement design stage, to tune and specify the solutions, and to demonstrate the resulting benefits.

Figure 4 shows samples of noise maps of an urban area before and after adoption of solutions for noise reduction.

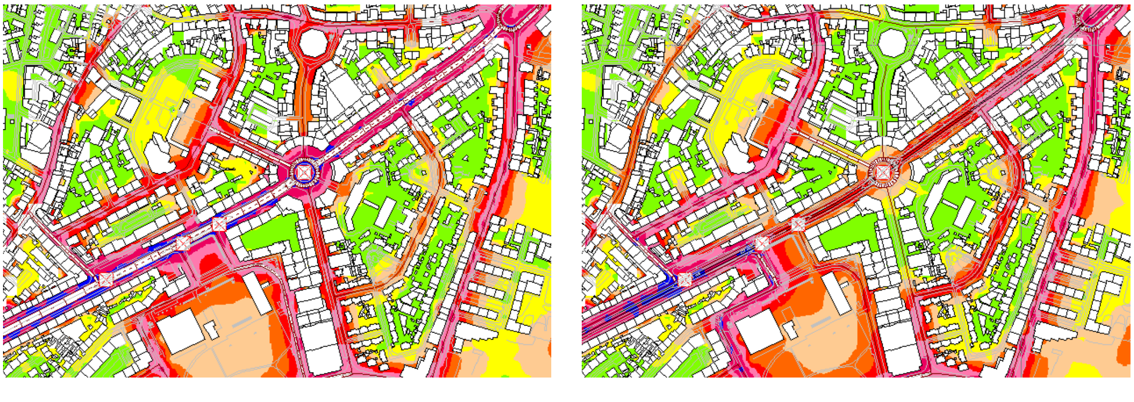

Figure 4. Samples of noise maps of an urban area, before (left) and after (right) implementation of noise mitigation measures

Noise mapping was also used to compare existing and future scenarios and to show the population the benefits of new measures and plans.

Figure 5 shows the use of noise maps as simple visual tools to compare “before” and “after” scenarios.

Figure 5. Comparison of noise maps for scenarios regarding road traffic changes; previous (left); future with new traffic diversion (right).

Noise maps were shown to be very useful in discussions with the populations and city officials since the color displays are easier to understand than numbers for noise levels. Such discussions with the stakeholders allowed the city councils to understand the full extent of the citizens’ expectation regarding the improvement of the urban environment, allowing the implementation of further measures and policies for mobility changes and urban development [6].

Qualitative Sound Maps

The concerns regarding the perceived quality of the acoustic environmental led to a comprehensive programme of study of the soundscape in urban parks [7]. These are areas where the soundscape composition (traffic noise, water sounds, music, animal and human sounds) is more complex than in the surrounding areas (essentially road traffic noise) and having components which are perceived as pleasant sounds, not noise. Since the quantitative noise maps are only able to provide values for the overall sound pressure levels, techniques were developed to draw qualitative sound maps based on perception differentiating between the different sound components [8].

Figure 6 shows a sample of the quantitative noise map of the Rossio Square in Lisbon where the overall levels in the central area are high. However, these levels are made of components which can be perceived as noise (in the sense of being unpleasant, disturbing, or useless), such as road traffic, and others which are in context which the place and either are not unpleasant or are even appreciated such as water sounds, music, or human and bird sounds [8].

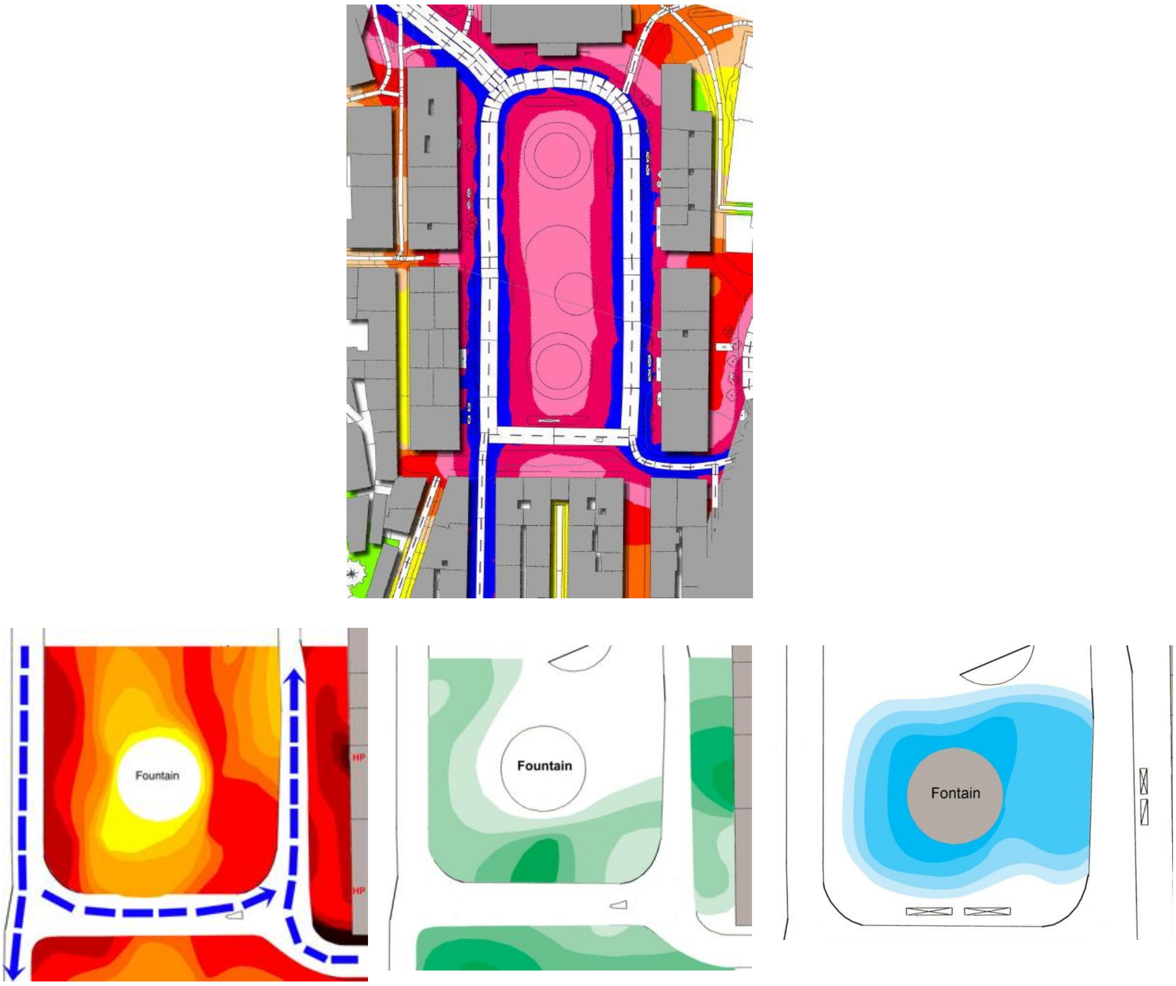

Figure 6. Sample of noise map of Rossio square, Lisbon (above); maps of perceived sound components (below): road traffic (left), music (middle), water sounds (right).

Figure 7 shows the sound maps of the different components of the soundscape in Principe Real square, also in Lisbon [9]. Each color represents a different sound component where the different shades correspond to 3 dB intervals. The lowest level represents the limit of audibility as perceived by the user of the place [9-10]. Of course, the overall sound pressure level in each place results from the added contributions of all sources.

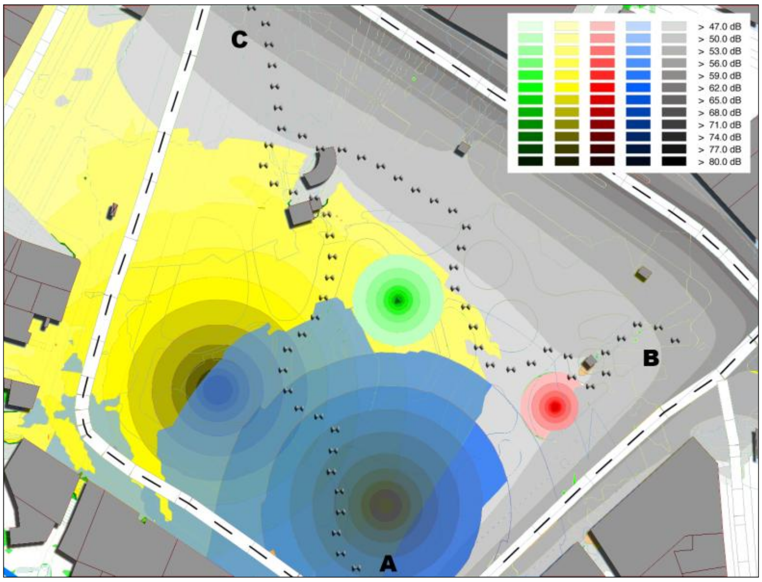

Figure 7. Map of the soundscape components of Principe Real square, Lisbon: road traffic (grey); children playground (yellow); people talking (blue); squawking ducks (green); bird singing (red).

These sound maps can be used as tools for the design of the soundscape in urban areas especially parks and areas of sound improved environment to provide sound differentiation and psychological restoration for the citizens [10].

CONCLUSIONS

Large scale noise mapping started in Portugal well before the European Environmental Directive (END) was approved in 2002. Lisbon airport noise maps exist since the early 1990’s and the Lisbon noise map was completed in early 2000. The Portuguese Noise Act of 2000 required all cities and transport infrastructures to draw noise maps and to prepare noise reduction plans where noise levels exceed specified limit values. Althoug the scope of maps and plans was not as wide as in END, this led to an extensive exercise of noise assessment and management.

For calculation, the interim methods were used as from 2006 when the END was transposed. For railway noise, although provision for use alternative methods was included in the legislation, a comprehensive study was conducted so as to adapt the RMR database classes to the characteristics of the national rolling stock. Results showing differences usually much less than 2 dB made the method perfectly fit for use.

Larger cities opted not just for strategic noise mapping but also for a more detailed level, producing a tool for planning and management purposes.

Action plans were developed to mitigate noise where the levels were found excessive, to control and manage noise for a sustainable development, and to protect areas where the acoustic quality is good. Strategies and solutions for noise mitigation and control were defined together with the responsible body officials and technicians but also with other stakeholders, especially the residents.

Noise maps were widely used both for tuning the design of noise mitigation measures and as communication tools with the population and with other technicians and decision makers to demonstrate the benefits of noise reduction solutions or discuss environmental protection strategies and resulting scenarios. These included the definition of quiet areas especially in urban areas.

Studies were also conducted in large cities, especially in Lisbon on the soundscape of urban parks where qualitative sound maps were developed, differentiating the different sound components in different layers of information.

ACKNOWLEDGEMENTS

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