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Urban Noise Pollution Assessment Techniques

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1. Introduction

An important factor for the life quality in urban centres is related to the noise levels to which the population is submitted. Several factors interfere with the amount of noise pollution throughout the city. Among them, and as one of the most important, is the traffic noise.
A major challenge is the quantification of the noise effects on the population. Not only high levels must be assessed but also the amount of people exposed to them is of great importance. This task is far from obvious since the sound propagation is affected by many environmental characteristics distinct in nature. The topology of the buildings and the topography may create quiet zones even in crowded neighbourhoods. Traffic may statistically vary. The population exposed might be resident but also fluctuate, not to mention the subjective nature of the sound perception itself.
In order to aid the urban planner cope with these difficulties, this chapter will comprehensively presents alternatives ranging from numerical simulation, called noise mapping, to measurement based noise monitoring.
Noise mapping techniques together with standards for the calculation of noise propagation are powerful tools to aid urban planners in correctly applying noise abatement measures in an economically feasible way. Nevertheless the results of such mappings rely on a great amount of data, location and strength of noise sources, ground geometry, location and geometry of buildings, etc. This work also discusses the sensitivity of the obtained simulated noise levels to the quality and precision of the geometric data available.
Actual measurements are however needed not only to verify the model assumed for the simulation but also for the noise pollution assessment itself. This can be achieved through local measurements of short duration or through long term monitoring in fixed places. The measurement techniques and procedures are addressed together with the creation of databases to help the decision making process of the urban planner

2. Sound Propagation and Topology

A noise map is a tool that delivers visual information of the acoustic behaviour of a geographic area either in a specified moment or in a statistical base. It is considered as tool to improve or to preserve the quality of the environment regarding noise pollution, allowing a comprehensive look at the problem of multiple sources and receivers.

Noise map is also an excellent tool for urban planning. According to Santos (2004), the use of noise maps techniques as a planning tool allows:

- Quantification of noise in the studied area;
- Evaluation of the population exposition;
- Creation of a database, for urban planning with localisation of noisy activities and mixed and sensible zones;
- Modelling of different scenarios of future evolution;
- Prediction of impact noise of projected infrastructure and industrial activities.

In Europe, the Directive 2002/49/EC of the European Parliament and of the Council, of 25 June 2002 relating to the assessment and management of environmental noise imposes to its Member States the elaboration of noise maps for cities with more than 250,000 inhabitants, due no later than 30 June 2007 (EC, 2002). These maps shall be reviewed, and revised if necessary, at least each five years after the date of their preparation. In Brazil, however, the presentation of noise maps by the city planners is still not an obligation. In Rio de Janeiro, specifically the local legislation, supported by the corresponding federal one, only foresees maximum acceptable levels of noise according to the occupation type or urban zone.

The elaboration of maps can be made using real measurements in points previously determined, using only prediction models through simulations or, in a mixed system, simulations can be complemented and verified with actual measurements. Of course the core of a noise map resides in the propagation model of the sound originating by the sound sources, and the model used for these sources itself.

The propagation model must take into consideration the usually high concentration of population, shops and a heavy traffic from particular vehicles and public transportation, in a general urban environment. Of course there are considerable differences between neighbourhoods of a big city, densely populated, and small city with lesser buildings and more free area. Although the result of the propagation of sound being quite different in these cases the mathematical model behind the calculations is the same. It must consider the effect of the ground topography, the presence of natural or artificial barriers, the effect of reflection and diffraction of the sound waves on buildings and facades but also on the ground itself. For the majority of commercially available software the propagation model is defined in national standards, which are incorporated in the calculation code. Table 1 lists some commonly found standards, from different countries, that establishes noise calculation procedures. Not only the propagation but the modelling of the sound generation is included, depending on the kind of source being simulated (Datakustik, 2005).

In this way, not only the results may be verified independently, but also the noise map can be presented according to the corresponding local legislation enforcing specific standards. Of course one still need to chose one of the available standards to perform the calculations for the case where no specific model is required (City of Rio de Janeiro, 1978, 1985, 2002, and ABNT, 2000).

The topography of the region is input to the software either as basic data from a CAD model or through the use of a aerial photographic image of the desired area with the corresponding terrain heights input manually. Usually, CAD database do not include only the topography of the neighbourhood under study, but also the individual building heights.

This kind of information may be available for the majority of great cities, otherwise the cost of a simulation will increase with the increase in time to input the data. Figure 1 shows the computer representation of the topography of the terrain, including also the buildings with their individual properties of an area under study (Pinto et al., 2005).

Type of Source	Standard or Calculation procedure
Industrial Noise	ISO 9613 incl. VBUI and meteorology according to CONCAWE (International, EC-Interim) VDI 2714, VDI 2720 (Germany) DIN 18005 (Germany) ÖAL Richtlinie Nr. 28 (Austria) BS 5228 (United Kingdom) General Prediction Method (Scandinavia) Ljud från vindkraftverk (Sweden) Harmonoise, P2P calculation model, preliminary version (International)
Road Noise	NMPB-Routes-96 (France, EC-Interim) RLS-90, VBUS (Germany) DIN 18005 (Germany) RVS 04.02.11 (Austria) STL 86 (Switzerland) SonRoad (Switzerland) CRTN (United Kingdom) TemaNord 1996:525 (Scandinavia) Czech Method (Czech Republic)
Railway Noise	RMR, SRM II (Netherlands, EC-Interim) Schall03, Schall Transrapid, VBUSch (Germany) Schall03 new, draft (Germany) DIN 18005 (Germany) ONR 305011 (Austria) Semibel (Switzerland) NMPB-Fer (France) CRN (United Kingdom) TemaNord 1996:524 (Scandinavia) FTA/FRA (USA)
Aircraft Noise	ECAC Doc. 29, 2nd edition 1997 (International, EC-Interim) DIN 45684 (Germany) AzB (Germany) AzB-MIL (Germany) LAI-Landeplatzleitlinie (Germany) AzB 2007, draft (Germany)

Table 1. Parameters needed for a noise impact study through a map

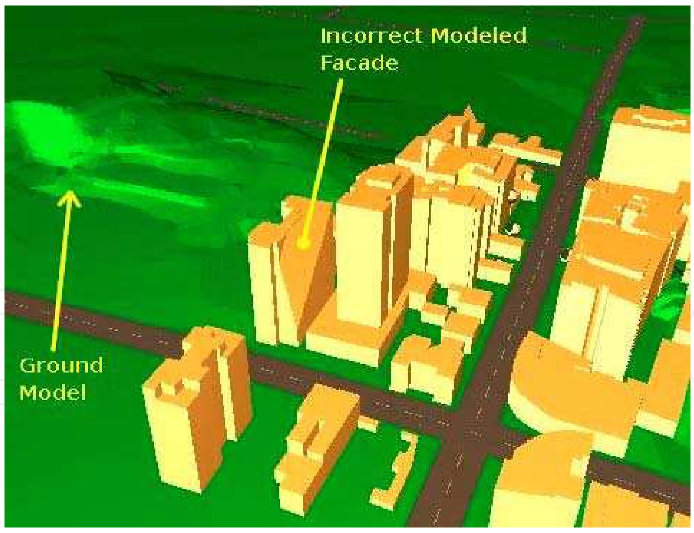


Fig. 1. Topography of a region under study with terrain and building elevations (only a partial number of buildings is depicted)

As a next step after the topological information is correctly inserted into the software database, which can be done in a very automated way from CAD programs, the noise sources must be identified and modelled. Several commercial software can be used to calculate noise maps, among them may be cited CADNA-A, Mithra, SoundPlan, Predictor, IMMI, LIMA, ENM, etc. To create the noise maps presented in this work the software CADNA-A was used. The modelling, following the procedures established in the standard being used, is based on different parameters (Table 2).

Source	Traffic noise	Type of vehicles (car, motorcycle, truck)
		Type of engines (gasoline, diesel)
		Mean velocity
	Industrial noise	
	Rail noise	
	Entertainment	
Surroundings	Road surface	
	Building heights	
	Street widths	
	Absorption coefficients (facades)	
Environment	Humidity	
	Temperature	
	Wind	
Demographic parameters	Number of inhabitants	
	Number of units per building	

Table 2. Parameters needed in a noise impact study

For instance when dealing with traffic noise the propagation is characterised by diverse parameters (type of vehicles, number of vehicles) and surroundings (height of the building, sound absorption coefficient of the facade, type of floor, width of the streets) influencing in noise propagation. Actually we can distinguish between a small number of source types (Kinsler et al., 1982):

- point source (like a loudspeaker, a valve, a vehicle, an aeroplane, an operating industrial equipment, etc.);
- line sources (like a road, a railway, piping system, etc.);
- area sources (like a parking lot, people gathering together, the openings of a tunnel, etc.);

which will be most basically modelled by their sound power. Table 3 shows the source of information for parameters.

Parameter	*Source of Information*
Terrain topography	Maps, CAD-models, Aerophotos, Satellite Images
Position and dimensions of buildings	Maps, CAD-models, Aerophotos, Satellite Images
Height of buildings	CAD-models, Field Information
Type of facade absorption	Field Information
Position and dimensions of noise barriers	CAD-models, Field Information
Height of barriers	CAD-models, Field Information
Position and cross section of roads	CAD-models, Field Information, Traffic Management
Traffic volume in roads	On-Line Information Systems, Traffic Management, Video Systems, Manual or Automated Counting
Percentage of heavy vehicles	Traffic Management, Video Systems, Manual or Automated Counting
Average vehicle speed	On-Line Information Systems, Traffic Management
Type of road paving	Traffic Management, Field Information
Sound power of generic sound sources	Direct Measurements, Equipment Specifications, Noise levels
Position of generic sound sources	CAD-models, Field information, Aerophotos, Satellite Images
Directivity	Direct Measurements, Equipment Specifications
Population density	Field Information, County Databases

Table 3. Source of information for parameters

The sound pressure levels produced by a sound source can not be considered an intrinsic characteristics of the source itself. The levels are rather a consequence of the interaction of the acoustic energy being introduced into the environment and the environment itself. It can be easily understood if one considers a loudspeaker operated in a well absorptive room like a studio compared with the same loudspeaker, fed with the same power, in a highly reflective environment like a bathroom. In the latter the reflection of the energy in the walls contribute to the sound level inside the room, whereas in the former the walls retains most of the energy, thus causing a smaller level.

Sound power, although in some circumstances being also influenced by the environment, can be regarded as a characteristics of the source itself and can be measured with different, standardised, procedures (ISO, 1994).

Starting from these data the program calculates the noise map of the selected zone. Nevertheless many factors may affect the correctness of the results obtained, i.e. of the model used. In order to validate the calculation, the simulated values from sound pressure levels should be compared with experimental measurements.

Since it can be expected that the noise predictions based on the German regulation RLS-90 would not match, for instance, the Brazilian vehicle fleet conditions this comparison is a primary issue. Based on the level differences between actual measurements and the simulation model, its parameters can be modified in order to get a better approximation of the real results by the simulation.

Firstly a general simulation of the neighbourhood noise levels is done, considering the volume of daily traffic, the average speed, the width of the streets, the type of asphalt, the sound power and location of other sources and the height of the buildings. To compare the values simulated with real measurements, a smaller sector may be considered in order to speed up calculations. With the simulation of the sector, the software generates a map of noise as shown in Fig. 2, which corresponds to the noise levels at a height of 1.5 meters, approximately the height of the measuring microphone. Table 4 shows a comparison between the simulation results and the real measured data (Pinto & Mardones, 2008).

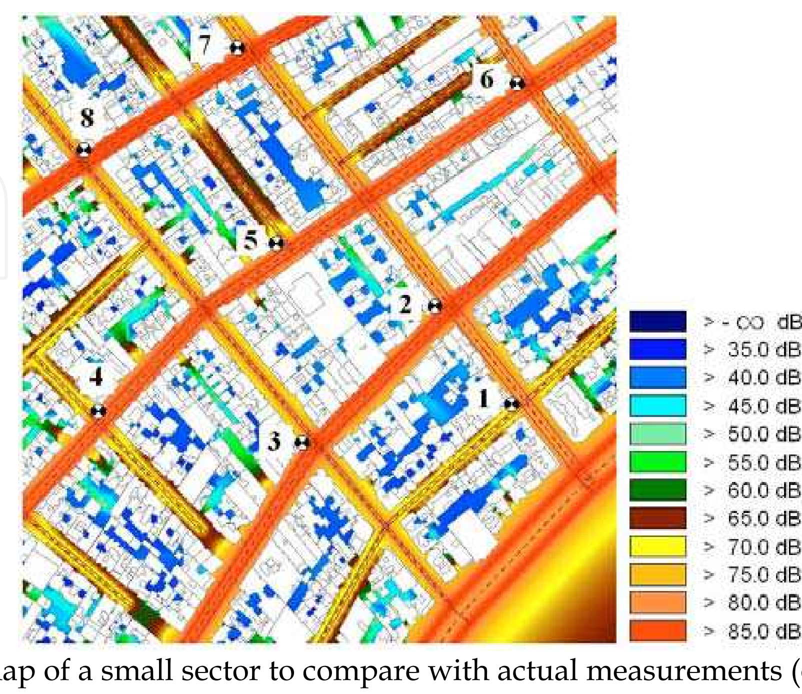


Fig. 2. Noise map of a small sector to compare with actual measurements (only traffic noise)

Point	Position	Measurement dB(A)	Simulation dB(A)	Difference dB(A)
1	Domingos Ferreira 76	65,1	65,7	-0,6
2	Domingos Ferreira/Figueiredo Magalhães	67,4	69,8	-2,4
3	Av. N.S.Copacabana 610	76	78,2	-2,2
4	Av. N.S.Copacabana/Figueiredo Magalhães	74,3	74,7	-0,4
5	Av. N.S.Copacabana/Santa Clara	73,5	73,6	-0,1
6	Santa Clara frente ao 98	70,5	70,6	-0,1
7	Av. Barata Ribeiro/Raimundo Corrêa	73,8	72,5	1,3
8	Av. Barata Ribeiro 535	74,8	76,7	-1,9
9	Av. Barata Ribeiro/Anita Garibaldi	71,8	73,3	-1,5
10	Av. Barata Ribeiro 432	77,6	77,4	0,2
11	Av. Barata Ribeiro/Siqueira Campos	73,6	75,6	-2
12	Rua Tonelero/Figueiredo Magalhães	71,7	75,8	-4,1
13	Rua Tonelero/Santa Clara	71,5	72,3	-0,8
14	Santa Clara 161	68,3	67,3	1

Table 4. Comparison between measurements and simulation after model correction

The parameters used in the simulation can then be modified in order to reduce the level differences obtained. It can be seen that the level difference is not the same at all positions, thus it may be quite challenging to try to adapt the model to meet all results in every situation. A lasting error of about 2dB or 3dB between measurements and simulation is therefore quite acceptable. Specifically for the case shown, which deals only with traffic noise, the vehicle volume at each street may be corrected to approximate the levels. This modification does not reflect bad information on the amount of traffic but rather the difference between the German and Brazilian vehicle fleets. Therefore it is advisable to verify the simulation, at least, in a restricted set of points, in order to adapt the sound source description to approximately reflect the measurements at these locations. After that more confidence can be inferred from the noise map obtained.

3. Mapping Results

The technique of noise mapping is a very powerful tool in urban planning. Not only the actual situation can be deeply studied but also, and probably the most important aspect, the noise pollution impact of every intervention of the city planners can be previously assessed. From a new layout of roads and avenues to the installation of an industrial facility, from new traffic orientation to the construction of a shopping mall, the sound pressure levels to which the population will be exposed can be determined from the model of the sound sources that may be considered. The necessary counter measures can be proposed and investigated in order to determine their effectiveness.

Although these studies are more commonly carried out in the process of identifying the environmental impact of major plants, like thermoelectrical power plants, their use should be extended and enforced to assess even the noise involved in the construction phase of an enterprise in a densely populated urban centre. Entertainment activities for a large number of people, ranging from shows in open spaces, like beaches, to the operation of a music club should be analysed in this way prior to official city approval.

Figure 3 shows a densely populated neighbourhood from the city of Rio de Janeiro, called *Tijuca*.

Fig. 3. Area of Tijuca in Rio de Janeiro (Google Maps)

A noise map study conducted in this area can be seen in Fig. 4, where the only source involved is the traffic noise. There are no remarkable sound sources of other kind in this area for it is a major residential neighbourhood.

It can be seen that the noise levels in the main avenues exceed tolerable limits, already due to the traffic noise alone. A reduction of municipal taxes for the most affected residences could be a first measure, if proposed in the city law, in order to bring the problem of noise pollution to attention of the administration.

Fig. 4. Noise map of Tijuca (only traffic noise)

Some open problems, specially in cities with an economical environment like Rio de Janeiro, is the quantification of the noise pollution in poor areas like the *favelas*. Coupled with that is the assessment of the noise impact from barely legal activities like popular music shows and parties (*Bailes Funk*) which are held in the favelas but affect the population both in the favela itself as well as in the regular city in the neighbourhood.

4. Conclusion

The assessment of noise pollution can be made through measurements which, however, are restricted to a limited number of points. The simulation of the sound waves propagation enables the study of a whole region in respect to the expected sound pressure levels as a result from existent sound sources. Of course, in order to perform a meaningful simulation, the environmental properties as well as the characteristics of the sound sources must be modelled. The results obtained may be gathered and presented graphically in a so called noise map. Actual measurements are used to verify and adjust the simulation to the real situation.

Specially in the case of urban centres noise maps allow the correct interpretation of the influence of distinct sources, the assessment of the sound pressure levels to which the population is exposed and the study of counter measures. The impact of major changes in the urban environment, like an industrial facility or a new road and traffic layout, can also be evaluated prior to implementation, together with the effectiveness of eventually proposed mitigation concepts.

The use of noise maps in the city planning is already incorporated in the European legislation but the Latin American, in general, and Brazil, specifically, laws can still be improved in order to enforce the compilation of noise maps and establishing goals to reduce the overall levels and the impact in the population. The noise map of a densely populated neighbourhood in Rio de Janeiro was presented.

5. References

ABNT - Assosiação Brasileira de Normas Técnicas (2000). *NBR 10151/2000 Acústica - Avaliação do ruído em áreas habitadas, visando o conforto da comunidade – Procedimento*, Rio de Janeiro, Brazil

City of Rio de Janeiro (1978). *Decree #1,601 from June 21st (1978)*, Diário Oficial do Município do Rio de Janeiro, Brazil

City of Rio de Janeiro (1985). *Decree #5,412 from October 24th (1985)*, Diário Oficial do Município do Rio de Janeiro, Brazil

City of Rio de Janeiro (2002). *Resolution #198 from February 22nd 2002 of the environmental board of the city*, Diário Oficial do Município do Rio de Janeiro, Brazil

Datakustik GMBH (2005). *CADNA Manual V3.4*, Greifenberg, Germany

EC (2002). *Directive 2002/49/EC of the European parliament and of the council of 25 June 2002 relating to the assessment and management of environmental noise*, Official Journal of the European Communities, L 189, pp. 12-26

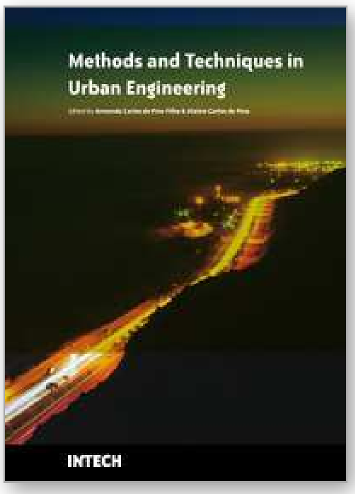
ISO (1994). *ISO 3744 Acoustics – Determination of Sound Power Levels of Noise sources Using sound Pressure – Engineering Method in an Essentially Free Field Over a Reflecting Plane*, International Standards Organisation, Genève

Kinsler, L.E.; Frey, A.R.; Coppens, A.B. & Sanders, J.V. (1982). *Fundamentals of Acoustics*, John Wiley & Sons, New York, United States of America

Pinto, F.A.N.C.; Slama, J. & Isnard, N. (2005). *Sensitivity of noise mapping results to the geometric input data*, In: Rio internoise 2005/the 2005 Congress and Exposition on Noise Control Engineering, work #1847, Rio de Janeiro, Brazil

Pinto, F.A.N.C. & Mardones, M.D.M. (2008). Noise mapping of densely populated neighborhoods - example of Copacabana, RJ, Brazil, *Environmental Monitoring and Assessment*, on-line, doi: 10.1007/s10661-008-0437-9, to be published

Santos, L.C. & Valado, F. (2004). *The municipal noise map as planning tool*, Acústica, Guimarães, Portugal, Paper ID: 162



Methods and Techniques in Urban Engineering

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A series of urban problems such as dwelling deficit, infrastructure problems, inefficient services, environmental pollution, etc. can be observed in many countries. Urban Engineering searches solutions for these problems using a conjoined system of planning, management and technology. A great deal of research is devoted to application of instruments, methodologies and tools for monitoring and acquisition of data, based on the factual experience and computational modeling. The objective of the book was to present works related to urban automation, geographic information systems (GIS), analysis, monitoring and management of urban noise, floods and transports, information technology applied to the cities, tools for urban simulation, social monitoring and control of urban policies, sustainability, etc., demonstrating methods and techniques applied in Urban Engineering. Considering all the interesting information presented, the book can offer some aid in creating new research, as well as incite the interest of people for this area of study, since Urban Engineering is fundamental for city development.