NOISE MAPPING OF DENSELY POPULATED NEIGHBORHOODS – EXAMPLE OF COPACABANA

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Abstract. *Copacabana is one of the most famous neighborhoods of the city of Rio de Janeiro but suffers from a high inhabitant density. One of the many environmental problems faced is related to noise pollution. In order to assess not only the noise levels, to which the population is exposed, but also to quantify the influence of architectonical aspects, the paper presents the steps taken towards a simulation of the noise emissions and propagation in this area. The results of the simulation are compared to measurements in different locations and daily-hours. The discrepancies are analyzed and the methodology is discussed in view of its application to a huge urban center like the city of Rio de Janeiro.*

Keywords*: Noise pollution, Simulation, Noise mapping, Traffic noise.*

1. INTRODUCTION

Urban noise is directly associated to human activities, especially in urbanized areas, and related to transport and industry development.

Copacabana is one of the most famous neighborhoods of Rio de Janeiro. Since the decade of 1960 the increasing fame has attracted more people than the area could hold comfortably. Therefore Copacabana suffered with real estate speculation until became full of residential buildings of many floors, mostly with very small apartment units.

This high population and tourist density causes the increase of traffic volume and the accompanying noise pollution, as expected in great urban centers. The increase of noise pollution is unsustainable and needs measures to be reduced and contained, since it is not only a source of annoyance, but also may lead to public health problems.

The assessment of noise in large cities represents a biggest challenge, owing to the high population density and the combination of different noise sources contributing to the overall acoustical environment. The assessment method must be carefully chosen in order to accurately describe it.

Due to the complexity, and mainly laborious and expensive task of measuring the acoustic situation of a place, simulations may be used through a prediction software informing noise levels in a faster way. It is clear that the simulation results must be compared to real measures, which can in turn be used to “calibrate” the model.

2. NOISE MAPS

A noise map is a tool that delivers visual information of the acoustic behavior of a geographic area either in a specified moment or in a statistical base. They are considered as tools to improve or to preserve the quality of the environment regarding noise pollution, allowing for a comprehensive look at the problem of multiple sources and receivers. It is also an excellent tool for urban planning

The use of noise maps techniques as a planning tool allows among other things (Santos 2004):

- Quantification of noise in the studied area;
- Evaluation of the population exposition;
- Creation of a database, for urban planning with localization of noisy activities and mixed and sensible zones.
- Modeling 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. These maps shall be reviewed, and revised if necessary, at least each five years after the date of their preparation.

In Brazil the confection of noise maps is still not an obligation. In Rio de Janeiro specifically the legislation only foresees maximum acceptable levels of noise according to the occupation type or urban zone. This legislation is supported by the corresponding federal legislation that deals with the problem in a similar way.

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.

3. ACOUSTIC SIMULATION

There have been developed many tools for acoustic simulation that had a great impact on the field of prediction and analysis of the acoustic environment of a city, thanks to the use of complex equations and calculations at modern computers. Nevertheless the calculation time and the required resources may be very restrictive, but the simulation applications are becoming still more powerful, allowing a more trustworthy analysis in lesser time (Tarrero 2005).

The study of the acoustic impact in a urban area considers a lot of parameters as in table 1:

Table 1. Parameters needed for a noise impact study

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	

4. SIMULATION PROGRAM

To create a noise map from Copacabana in this work the software CADNA-A was used. CADNA-A (**C**omputer **A**ided **D**esign **N**oise **A**batement) is a program for calculation and presentation of noise levels from environmental noise, as well as a program for prediction and assessment in relation to the acoustic annoyance. It works in Windows with a simple user interface incorporating PCSP technology (Parallel Controlled Software Processing). It is thus possible to work in parallel, in the same project, using a computer local area network.

CADNA-A takes national guidelines and standards into account for the calculations. Each type of sound source, whether road, railway, or any general point, line or area source is considered according to the regulations valid for the relevant type of source. Since the Brazilian standards do not impose rules in order to take into account the propagation, reflexion, diffraction and other effects to obtain noise maps from the simulations, the work presented here is based on the German rules.

With CADNA-A is possible to get statistical values of acoustic impact in the population with graphical presentations in horizontal, vertical and in facade maps.

5. DESCRIPTION OF THE AREA

Due to high concentration of population, shops and a heavy traffic from particular vehicles and public transportation, the area to be studied covers most of Copacabana, in the South of Rio de Janeiro. Firstly a general simulation of the neighborhood traffic noise levels was done, considering the volume of daily traffic, the average speed, the width of the streets, the type of asphalt and the height of the buildings. To compare the values simulated with real measurements, a smaller sector was considered here.

5.1 Simulation

The topography of the region is input as basic data from a CAD model of Rio de Janeiro. The database used in simulations do not include only the topography of the Copacabana, but also the building heights individually. This kind of information shall be available for the majority of the great cities. 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 are identified. In this case the main source of noise is the urban traffic. This is characterized by diverse parameters (type of vehicles, number of vehicles) and surroundings (height of the building, coefficient of absorption, type of floor, width of the streets…) influencing in noise propagation. With these data the program calculates the noise map of the selected zone. To prove its veracity, the simulated values are compared with experimental measurements.

With the parameters of the sector introduced, the software generates the map of noise shown in figure 1, which corresponds to the noise levels at 4 meters of height. Figure 2 shows an aerial photograph of the same region, approximately.

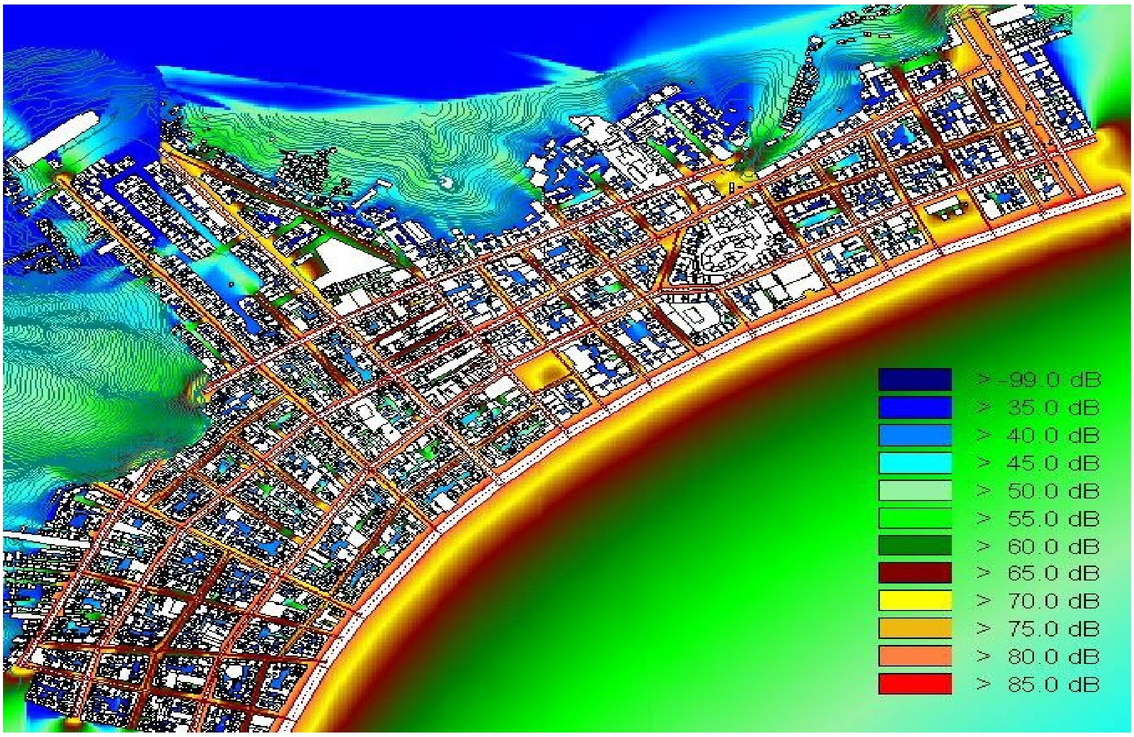

Figure 1. Traffic noise levels simulated – 4m height

Figure 2. Picture of Copacabana (Google Earth)

A smaller sector is chosen to establish a comparison with real measured data. This sector corresponds to the central zone of the neighborhood of Copacabana, between the Atlantic Avenue and Toneleros Street and between streets Raimundo Corrêa and Siqueira Campos. This area was selected due to the high number of vehicles in the main streets, though also presenting some quieter places. The daily traffic volume data was supplied by CET-Rio, the traffic engineering company of the city of Rio de Janeiro. The simulation of this sector was redone for a height of 1,5m in order to allow a comparison with real measurements done with portable sound level meters. Fig. 3 shows an aerial photo of the sector indicating the street names.

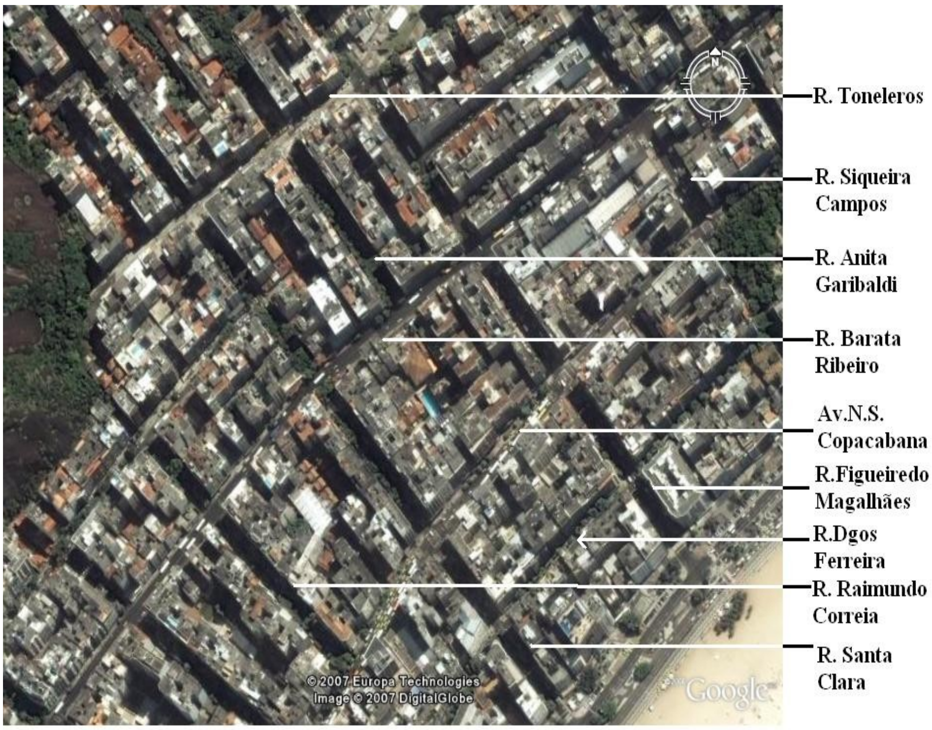

Figure 3. Aerial photo of the sector of Copacabana chosen for measurements (Google Earth)

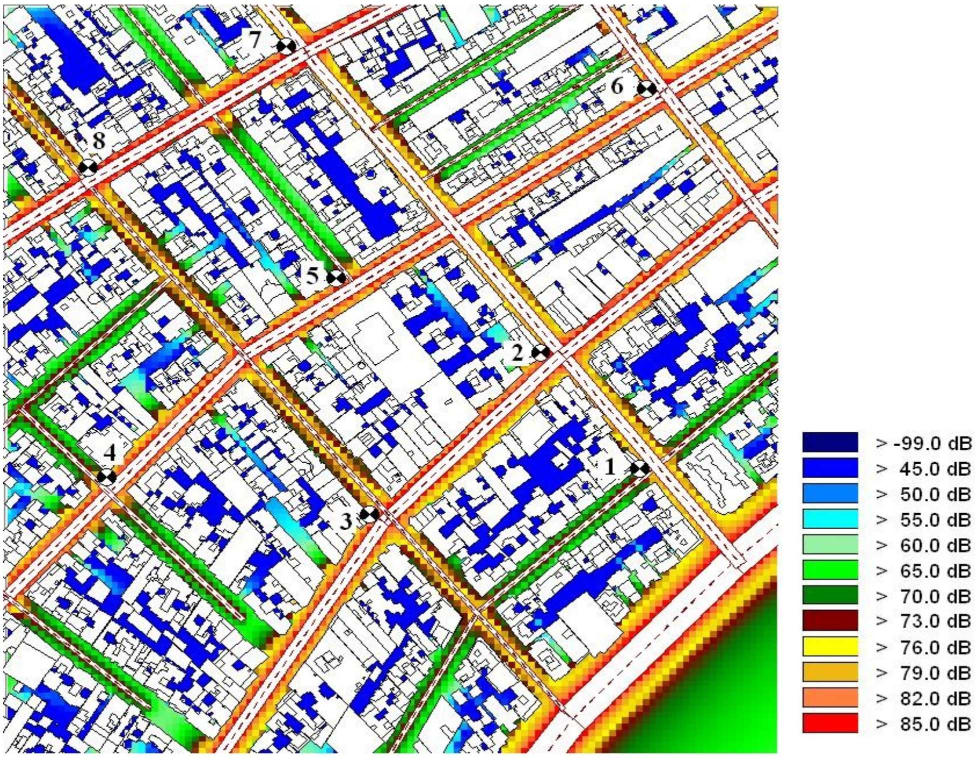

Figure 4. Simulation of the sector corresponding to figure 3 – Traffic noise at 1,5m height

5.2 Measurements

Experimental measurements consist of the equivalent sound pressure level (Leq) in each receiving point, for a period of at least 5 minutes. The Environmental Board of the City of Rio de Janeiro adopted the Leq as metric for the evaluation of the impact of environmental noise in the city legislation.

The Leq as a continuous equivalent sound pressure level for a determined measurement point, obtained from a time varying noise in a defined period of time, is equal to the level of a steady noise that would correspond to the same acoustic energy received during this interval of time. The Leq can be used to assess continuous noise sources like traffic, industries or entertainment events, for example, and proves useful when two situations are to be compared (WHO 1999).

In order to perform the experimental measurements 8 points have been considered in major corners of the chosen sector in Copacabana, described in table 2, and figure 4. The measurements were done in three periods of time; morning, afternoon and night and in different days of the week in each point. The receivers are situated at approximately 1,5m height from the ground.

Table 2. Locations for Leq (5 minutes) measurements in Copacabana

Point	Localization	Measurement dB(A)	Simulation dB(A)	Diference dB(A)
1	Domingos Ferreira/Figueiredo Magalhães	67.4	69.8	2.4
2	Av.N.S.Copacabana/Figueiredo Magalhães	74.3	74.7	0.4
3	Av.N.S.Copacabana/Santa Clara	73.5	73.6	0.1
4	Av. Barata Ribeiro/ Raimundo Corrêa	73.8	72.5	-1.3
5	Av. Barata Ribeiro/ Anita Garibaldi	71.8	73.3	1.5
6	Av. Barata Ribeiro/ Siqueira Campos	73.6	75.6	2
7	Rua Tonelero/Figueiredo Magalhães	71.7	75.8	4.1
8	Rua Tonelero/Santa Clara	71.5	72.3	0.8

The equipment used was an integrating sound pressure level meter Brüel & Kjaer Type 2233 previously acoustically calibrated.

5.3. Comparison of results

Analyzing the results it can be seen that the differences between the measured and simulated values are small, being less than 2dB. The exceptions are point 7, at the corner of the Tonelero and Figueiredo Magalhães streets, where the difference was of 4,1dBA, and point 1 at the corner from Domingos Ferreira and Figueiredo Magalhães with 2,4dB.

In point 7, the subway station Siqueira Campos appears as an important source, which was not considered in the previous simulations, justifying the difference. Further simulations must consider this source as well, along the traffic noise. Point 1 is located in a region of low traffic volume at Figueiredo Magalhães, thus being more sensible to individual fluctuations of number of vehicles passing by during the actual measurements, when compared to the statistical noise level obtained from this simulation. A longer period for the Leq measurement or a closer look at the actual traffic on that street portion may bring the difference to a value less than 2dB.

According to the Urban Zones of the City of Rio de Janeiro (stand from 1999), shown in figure 5, the Administrative Region of Copacabana corresponds to Residential Zone 2, Residential Zone 3 and Tourist Zone 1. There are also special cases considered in the *Centros de Bairro* 1,2 and 3 (Neighborhood Centers).

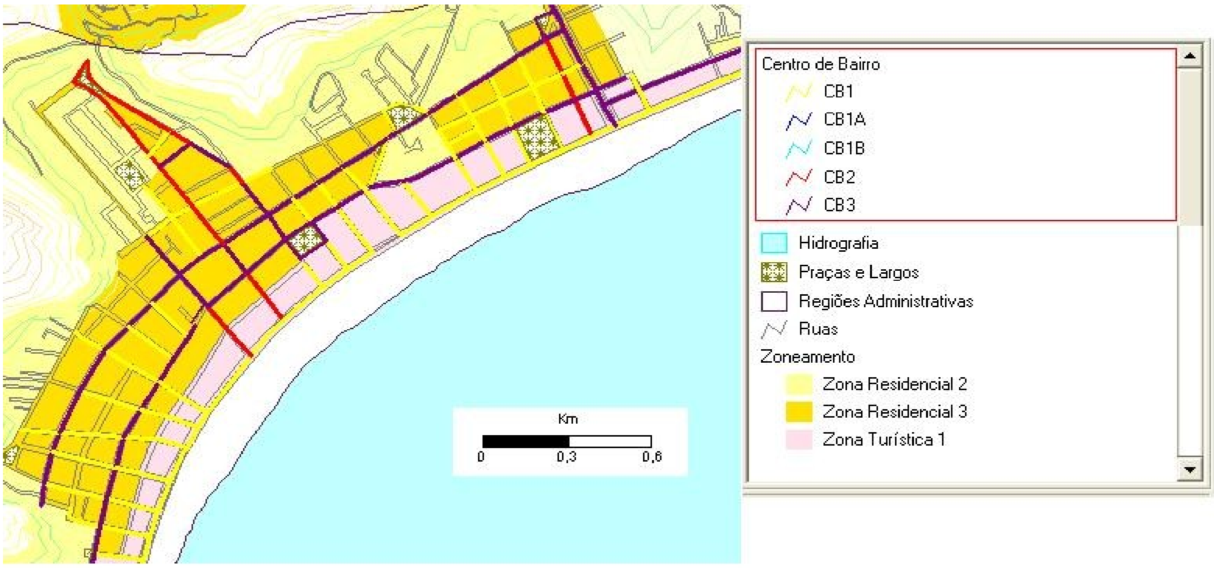

Figure 5. Urban zoning of Copacabana.

The *Decreto nº 5.412*, of 24 October 1985 and the *Regulamento nº 15 - Da Proteção Contra Ruídos*, approved by *Decreto nº 1.601*, of 21 June 1978 indicates maximum levels of noise allowed in theses zones as in table 3:

Table 3. Allowable noise limits from selected zones – City of Rio de Janeiro

Zone	Destination	Code	Maximum Noise Level Allowed (Day) dB(A)	Maximum Noise Level Allowed (Night) dB(A)
Zona Residencial-2	Multifamiliar residences and primary schools	ZR-2	55	50
Zona Residencial-3	Multifamiliar, shops and services in exclusive buildings	ZR-3	60	55
Zona Turística-1	Multifamiliar and touristic activities	ZT-1	65	60
Centro de Bairro	Shops	CB de ZR-1	60	55
Centro de Bairro	Shops	CB de ZR-2	65	55
Centro de Bairro	Shops	CB de ZR-3	65	60

On the other hand the Brazilian Standard NBR 10151/2000 indicates maximum levels for external noise, in dBA, which should be followed by municipal regulations according to the type of land use as in table 4:

Table 4. Allowable noise limits from selected zones – Brazilian Standard NBR 10151/2000

Use	Day dB(A)	Night dB(A)
Residential	55	50
Business and Administrative	65	60

According to the *Resolução SMAC N.°198* of 22 February 2002, which enforces standardization of procedures for the assessment of noise pollution, the external levels used as evaluation of criteria in accordance with 10151/2000 NBR and municipal zoning are:

Table 5. Guidelines for the comparison between NBR10151 and local regulations – Rio de Janeiro

Use (NBR10151)	Zone	Day dB(A)	Night dB(A)
Mixed, mostly residential	ZR 1, ZR 2	55	50
Mixed, mostly business and administrative	ZR3, CB de ZR	60	55
Mixed, with leisure (entertainment) activities	ZT, CB de ZT	65	55

It can be seen that the background noise due to traffic in all selected points shows levels already above of the allowable ones. This background noise shall thus be used as criteria for the assessment.

6. RESOURCES EVALUATION

In order to be generate the noise map a lot of effort, in terms of resources like manpower, simulation time, computer resources, information and data acquisition, etc..., must be made. The main objective of this research is not only to provide an adequate overview of the noise impact in Copacabana, but to establish and quantify the difficulties and the necessary resources needed to create a noise map of a city sector like Copacabana and further estimate the costs involved in the mapping of the whole city of Rio de Janeiro.

It is expected clearly that the use of the simulation as tool to create these noise maps shall reduce time, man power necessary and the cost as a whole. Among other things the availability of a precise CAD database of the topography and buildings is of major concern in this process. The city of Rio de Janeiro, however, does have such a database, although from some years ago. It can be of course easily updated. Actual information about traffic volumes is also an issue which is more difficult to handle. The traffic engineering from the city does possess some information but not from the whole city. Local assessment of the number and type of vehicles in different parts of the cities, specially in residential neighborhoods, must then be accomplished. Nevertheless, as seen in related studies (Pinto et alli 2005), the eventually poor precision of such data might not be a concern.

The equipment needed for the accomplishment of this work was: the software of simulation CADNA, a PC-type computer, a sound level meter Bruel & Kjaer Type 2233 and a calibrator.

The neighborhood of Copacabana has an area of 7,84 km² and, besides the heavy traffic, there is an enormous amount of buildings which means a great amount of data to be processed and verified. Considering this situation, in order to make the simulation more efficient, the area was divided in nine subsectors which were simulated separately and the obtained maps had been later joined.

The simulation of the whole area took 2 full weeks of running time to be concluded. In the case of the minor sector of Copacabana, the simulation takes 4 hours. These calculation times were obtained by a single computer. The use of a network can improve this remarkably.

Of the carried through measurements, 112 had been considered for the comparison. The measurements of Leq had been carried through during the different days of the week, in the periods of morning, evening and night.

7. CONCLUSIONS

The results in this work demonstrate that the environmental noise is an important issue in Copacabana, Rio de Janeiro. The studied sector, which is characterized by a high population density and by heavy traffic of vehicles from different kinds, presents background levels higher than the recommended by the regulations applicable. The analysis of the results shows that the noise levels in all the measured points in Copacabana, and as can be seen from the noise map, in a large area of the neighborhood are over the allowed values. The main cause being the traffic noise.

The technology of noise mapping demonstrates to be an excellent means to deal with the problem of noises pollution. The simulations are powerful tools to be used in the urban planning. Many parameters must be known previously or be identified to serve as base for the correct representation of the physical effect. Nevertheless the most laborious, like topography and buildings, can be input to the program almost automatically from CAD databases. The correct modeling of the sound sources plays the most important role in the results.

The noise maps in small scale, as in the case of Copacabana, in Rio de Janeiro, constitutes a real important first step for a future work in the whole city, as already needed in Europe, and may be also enforced in Brazil.

Another important thing to be considered in future works is the study of the number of inhabitants who are affected by the noise levels.

CADNA-A is an excellent solution for simulation, that allows the acoustic environment of a sector to be assessed, characterizing the sources and its surroundings. Comparing the data measured with the simulated ones there was an excellent agreement.

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