MODELLING THE URBAN NOISE OF THE CITY OF BELÉM (BRASIL)

PACS: 43.50.Rq

Moraes, Elcione1; Simón, Francisco2; Guimarães, Luís1; Moreno, Antonio2
1Universidade da Amazônia, Av. Alcindo Cacela, 287; 66060-902. Belém, Brasil;
2 Instituto de Acústica, CSIC, C. Serrano, 144; 28006. Madrid; Spain

ABSTRACT
Noise can be considered as a pollution source for modern societies, so great effort is currently
done to its characterization and control. The key tool to manage this kind of problem is noise
map. Prediction noise maps have helped to extend and facilitate the diagnosis of urban noise
pollution. Reliability and accuracy of their results are very dependent on input data which in turn
depend on a set of geographic and social characteristics of the city being studied. Under these
conditions using a general urban noise prediction model for different cities can be a risky
strategy and produce significant errors. In this work, a noise model for the city of Belém, Brasil,
has been developed based on environmental noise measures carried out for a few of its
districts. Then, this model has been applied to predict the noise of other districts that were not
measured.

INTRODUCTION
The city of Belém is located in northern Brazil, at latitude 1 degree 28 minutes south. It has
800,000 inhabitants, nevertheless in its outlying area live about 1.600.000 people. The local
weather is tropical, that is, warm and humid with average annual temperatures around 28ºC,
and humidity of 85 %. Wind velocity is between 2 and 4 ms$^{-1}$ at 2 metres height with northeast
prevailing direction [1].

The first stage of the noise map of Belém (BNM) was developed between 2002 and 2004. The
BNM shows the noise levels for 18 city districts. The sound pressure levels have been
measured at 230 points placed on a squared mesh of 400 metres interval length, during the day
period between 7:00 and 22:00 hours [1].

Measuring the whole city is so complex, costly and labour intensive that at this moment the goal
is to use previously measured data from others districts to characterize the noise as a function
of urban parameters, and using software to calculate the acoustic field in the rest of the city in a
reliable way. In this way, pressure levels can be quickly obtained all over the city, and besides,
these results could be included in an urban management system.

In this work we show the study that is being carried out to update the BNM and extend it to the
rest of the city. A commercial software will be used, in which the inputs are geographical and
geometrical data such as the width of the streets, its designated use (commercial, pedestrian,
business, etc.), heights of buildings, in addition to specific traffic information. The output will
obviously be the sound pressure levels over the areas under study. Once the model is
completed it will work as a tool to predict the environmental impact of proposed traffic routes
and to help solving other general urban management problems.

URBAN NOISE SITUATION IN BELÉM
Given the disordered way the urban areas have grown in Brazil; the environmental problems
have being increasing with time. Currently, near 80% of brazilian people live in towns with a
random development pattern that have given rise to problems such as: areas with a high
density of business companies, vehicles, and people; an increase of built surfaces, destruction of green areas and nature reserves, etc. All these problems have repercussions on quality of life and public health conditions [2].

Belém is a good example of all these problems; it has suffered an increasingly disordered and chaotic development. As a consequence, environmental conditions have largely changed, especially in the city centre with a high density of buildings. During the last decades its development has taken place with inadequate planning that has consequently influenced in the quality of life of the inhabitants.

On the other hand, from a cultural point of view, in tropical regions due to very mild weather conditions a number of activities are performed outdoors, thus producing a noise excess in urban areas [3].

Nevertheless, establishing rules, methods or any kind of noise control, implies a complex study that must collect all the data about the noise origins, propagation conditions from source-to-receiver, weather conditions, economic factors, social and cultural characteristics, as well as the architectural design of buildings and town itself.

The BNM is the first diagnostic tool to the existing noise in Belém. Although it has been developed for the day period, between 7:00 and 22:00 hours, it is not difficult to understand that the greater amount of complaints made to the local Administration are due to the nightlife which represents a principal noise source. In any case, it is the noise produced by the traffic that presents the main contribution to the overall noise.

18 city districts were studied. Subjective and objective data were collected to obtain sound pressure levels and human response [4]. Higher noise levels range from 70 dB to 78 dB A-weighted in 5 districts, including the 3 central districts with mainly business and commercial areas. Districts with lower sound pressure levels are in the surrounding areas, where sound pressure levels in the range 61 dB to 73 dB A-weighted were measured. So all the inhabitants of the studied areas, about 650,000 people, are exposed to levels higher than 60 dB A-weighted during the day.

Figure 1 shows the noise map of Belém for the time interval from 17:00 to 18:00 hours, which is the time interval with highest noise pollution.

Figure 1: Noise map of Belém for the time interval 17:00 – 18:00 hours.
METHODOLOGY

In this study, the sound pressure levels measured in the field become the input data that will allow the unknown parameters of our model to be obtained. These unknowns are related with the number, the type and the velocity of vehicles, and the type of street. The first step is to split up the town streets into categories related with their noise levels, and their traffic and street characteristics. This approach has shown to give good results in noise planning [5, 6].

Here, we will not only use the traffic characteristics of the streets, but their geometric and architectural information, and also their designated use (residential, commercial, services, etc.).

Street characterization

Buses are the only public transport system in the town with a route frequency of 1663 vehicles/day, and this is why the street characterization has been based on these routes. In addition, the use of each street as a function of its dominant activity in every section has been considered, as well as its width, its physical characteristics of the building, traffic flow and vehicle type (cars, heavy or light vehicles, and motorbikes).

All in all, these parameters give a great number of combinations and as a consequence the number of street types should also be large. For this reason, categorization has been carried out by district, starting with ones where the SPL and traffic data are known. Once the set of streets type has been defined, the model has been used for the remaining districts.

The noise generated by the community and from commercial activities in pedestrian streets can be even higher than that generated by traffic (comparing streets with similar characteristics). So these streets will be studied as a special case in our model where their own properties are taken into account.

Due to the importance of the vehicle type in analytical noise models, traffic flow has been classified into cars, heavy vehicles and motorbikes. Doing so we define the flow as low when there are less than 50 cars and 5 heavy vehicles (HV) per hour; medium-low from 51 to 100 cars and from 6 to 10 HV; medium from 101 to 250 cars and from 11 to 20 HV; medium-high from 251–500 cars and from 21 to 50 HV; high from 501 to 750 cars and from 51 to 100 HV and very high more than 751 cars and more than 101 HV per hour. Tables 1, 2 and 3 show the street types studied together with their characteristics, traffic flow, and street width for three of the districts studied.

Table 1: Street types in the district of Campina

<table>
<thead>
<tr>
<th>CASE</th>
<th>CHARACTERISTICS</th>
<th>TRAFFIC FLOW</th>
<th>STREET WIDTH</th>
<th>VEHICLES PER HOUR</th>
<th>$L_{day}$</th>
<th>CALCULATED $dB$ A-weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 floors. Mainly commercial. (no bus)</td>
<td>Low</td>
<td>10m</td>
<td>10-50 light vehic. 1-5 heavy vehic.</td>
<td>64 - 70</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2 floors. Mainly residential. (no bus)</td>
<td>Medium-low</td>
<td>10m</td>
<td>50-100 light vehic. 6-10 heavy vehic.</td>
<td>72 - 74</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2 floors. Mainly commercial. (no bus)</td>
<td>Medium</td>
<td>10m</td>
<td>200-250 light vehic. 6-10 heavy vehic.</td>
<td>74 - 75</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Road with water central channel. 2-10 floors. Mainly residential. (bus)</td>
<td>Very high</td>
<td>2 ways: 15m Channel:9,50m Total: 39,50m</td>
<td>200-250 light vehic. 150-200 heavy vehic.</td>
<td>77 - 79</td>
<td></td>
</tr>
</tbody>
</table>
### Table 2: Street types in the district of Batista Campos.

<table>
<thead>
<tr>
<th>CASE</th>
<th>CHARACTERISTICS</th>
<th>TRAFFIC FLOW</th>
<th>STREET WIDTH</th>
<th>VEHICLES PER HOUR</th>
<th>L_{day} CALCULATED dB A-weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2-15 floors. Mainly residential.</td>
<td>Low</td>
<td>10m</td>
<td>10-50 light vehic. 1-5 heavy vehic.</td>
<td>63 - 69</td>
</tr>
<tr>
<td></td>
<td>(no bus)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2-15 floors. Mainly residential.</td>
<td>Low</td>
<td>15m</td>
<td>10-50 light vehic. 1-5 heavy vehic.</td>
<td>61 - 68</td>
</tr>
<tr>
<td></td>
<td>(no bus)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2-15 floors. Mainly residential.</td>
<td>Medium-low</td>
<td>10m</td>
<td>51-100 light vehic. 6-10 heavy vehic.</td>
<td>69 – 71</td>
</tr>
<tr>
<td></td>
<td>(no bus)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2-20 floors. Mainly residential.</td>
<td>Medium-high</td>
<td>15m</td>
<td>250-500 light vehic 21-50 heavy vehic.</td>
<td>72 – 76</td>
</tr>
<tr>
<td></td>
<td>(bus)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 3: Street types in the district of Cidade Velha

<table>
<thead>
<tr>
<th>CASE</th>
<th>CHARACTERISTICS</th>
<th>TRAFFIC FLOW</th>
<th>STREET WIDTH</th>
<th>VEHICLES PER HOUR</th>
<th>L_{day} CALCULATED dB A-weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2-3 floors. Mainly residential.</td>
<td>Low</td>
<td>15m</td>
<td>10-50 light vehic. 1-5 heavy vehic.</td>
<td>61 - 67</td>
</tr>
<tr>
<td></td>
<td>(no bus)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2-3 floors. Mainly residential.</td>
<td>Medium-low</td>
<td>10m</td>
<td>51-100 light vehic. 6-10 heavy vehic.</td>
<td>69 – 71</td>
</tr>
<tr>
<td></td>
<td>(no bus)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2-3 floors. Mainly residential.</td>
<td>Medium</td>
<td>20m</td>
<td>101-250 light vehic 11-20 heavy vehic.</td>
<td>70 - 73</td>
</tr>
<tr>
<td></td>
<td>(bus)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2-10 floors. Mainly residential.</td>
<td>Medium</td>
<td>15m</td>
<td>101-250 light vehic 11-20 heavy veh</td>
<td>69 - 72</td>
</tr>
<tr>
<td></td>
<td>(bus)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2-10 floors. Mainly residential.</td>
<td>Very high</td>
<td>15m</td>
<td>501-750 light vehic 250-350 heavy veh</td>
<td>75 - 81</td>
</tr>
<tr>
<td></td>
<td>(bus)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RESULTS AND DISCUSSION

Although flow traffic data are the most important ones when predicting noise levels, geographic data related with contextual town characteristics have been shown to be important as well. Comparing prediction with experimental results it can be seen that the 80% of the results agree within ±1dB A-weighted and that no result differs from the measurements by more than 2 dB A-weighted.

Usually the values obtained by simulation are higher than the measured values. In some cases, the difference can be significant (as high as 10 dB A-weighted). So, simulation models do not always represent the reality. The main differences happen essentially at individual points such as road junctions, roads with uneven surfaces, and roads with intense traffic. For these reasons it is necessary to complement the calculation maps with additional measurements. [7]

Based on the results of this study, we conclude that in some situations there are significant discrepancies between the simulated values and the measured in-field values. It would thus be necessary to study several situations for different sets of parameters that play a role in the prediction programs and to identify the parameters that have the larger influence.

CONCLUSIONS

The new method has been applied to construct Belém’s noise map. This is seen to provide a more practical and efficient solution. It does not require performing large numbers of measurements and allows noise levels to be accurately predicted by means of the categorization of city streets based upon traffic, geometrical and geographical data.

As pointed out in other works, traffic data is the most important parameter to take into account; its classification by the proportion of heavy and light vehicles turns to be quite necessary to get good results. Nevertheless, the best agreement is achieved when architectural and urban characteristics are taken into account in the model of street types.

When using only vehicle traffic data the categorization method employed is inaccurate, and it is necessary to include the street width and the heights of the buildings.

We find few differences between the measured levels “in situ” and those calculated by the program, however, we have detected bigger discrepancies in the streets with high or very high traffic flow.

References: