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USING A GIS TOOL TO PLAN THE ACOUSTIC URBAN ENVIRONMENT

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ABSTRACT
This paper describes a set of GIS-based tools intended to provide public administrators with a methodology enabling a proper assessment of the acoustic impact within the urban environment. It is clear that adequate assessment of the environmental impact which may result from the economic development can only be carried out if suitable tools are available to the administrators, enabling proper supervision of land occupation. A model establishing the correlation between the spatial distribution of impacts and the relevant activities is developed. This model has been implemented as a prototype in a GIS environment, using Belo Horizonte's geographic database, which is intended to represent a typical large Brazilian city situation. Initial field measurements compare favorably with this prototype, indicating the feasibility of the proposed approach.

1 - INTRODUCTION

Large cities are affected by a series of environmental problems. Environmental influences that may have a detrimental effect on life quality include among others pollution caused by noise and gas emissions, and other safety hazards, associated to the attraction of high numbers of resulting from the concentration of economic activities in urban centers. Excessive noise seriously degrades the quality of the environment and in general around 70% of the inhabitants of large cities usually describe noise related disturbances as a very important factor affecting life quality [1]. The main sources of noise in urban centers are traffic, building and public works, and other activities such as industries, commerce, and services. However, the quantity of noise generated by each activity varies, according to its characteristics (such as the intensity of use and type of machinery or the use of loudspeaker systems) and to the installation of noise control devices.

The variety of environmental related issues faced by the municipal administrator requires the use of adequate tools if adequate decisions are to be reached. GIS tools are a powerful resource ideally suited to cope with this problem, particularly as plays a key role in acoustic models. The present work assumes a simple model of the distribution of sound through space and a classification of noise sources, aiming at the formulation for the bases of a spatial decision support system. This system is particularly valuable to environmental control organizations, also helping public administrators to decide on the licensing of new noise-generating activities [1].

The model has been implemented by PRODABEL (the data processing design agency of the Belo Horizonte, Brazil, also responsible for managing the town's digital cartographic database) as a prototype. This city with around 2.5 million inhabitants, it is a very good study subject, with plenty of acoustical, topographic business variations which turn it into not only a worthy subject of study but also as a object with vast prototyping possibilities.

2 - AN OVERVIEW OF THE PROBLEM

Initially, it is important to emphasize that the environment is dynamic, and is constantly on a mutation process. This is particularly true in the urban environment, where the intensity and speed of changes introduced by human activities make the mutations very difficult to monitor. It is also important to realize that many of the most important phenomena depend on seasonal effects. Generally speaking, controlling noise pollution can be achieved by two separate strategies. The first is to enforce the installation of noise control devices, in situations where compliance with the law is not observed (*coercion*). The second is to establish policies that disallow the concentration of activities in areas where there are already indications of pollution (*prevention*).

In order to characterize and identify urban noise pollution, it is necessary to develop a mathematical model in which noise sources and obstacles can be approximated and geographically distributed. Additionally, related environmental parameters such as temperature or winds need also to be considered. The model can then be used to generate an approximation of the noise distribution, which can then be implemented.

3 - ACOUSTIC MODELING

Acoustic modeling applied to GIS tools is carried out roughly speaking very much in the same way as conventional acoustic modeling. That can be summarized from the urban noise modeler point of view as the determination of the noise level spatial distribution in the neighborhood of an emitting source, and how the effects of all the present sources can be combined in order to estimate the parameters of the resulting acoustic field [1]. The resulting model can then be implemented as a spatial decision support system.

Initial considerations about wave fronts and source type are essentially a function of geometry and wavelength [2], [3]. Punctual sources are often preferred in urban environmental studies for a varied of practical reasons, at least during the initial evaluation studies. Standard SPL A weighted sound levels are suitable and can be evaluated by means of traditional techniques found in several references such as [2].

Urban noise sources can be conveniently classed as fixed (comprising a variety of commercial and industrial activities) and moving (mainly traffic noise). In the present study the noise the noise impact activities (sources) have been assumed to be simple punctual sources fixed on the ground, radiating all the energy to a quasi-infinite space. A convenient method described by [4] has been used for the traffic noise model. The vehicles have been taken as punctual noise sources, travelling in a straight line along the axis of perfectly rigid carriageways, with constant speed and spacing. Fixed sources also require a good standard evaluation of the directivity index, as defined in [2]. Finally it should be mentioned that sometimes exact quantification of the source parameters inside a large town is not feasible. When this happens the source properties have to be determined by their legal definition, i.e., a certain activity produces an established noise output.

4 - GIS IN ACOUSTIC ANALYSIS

There are several different ways in which acoustic data can be presented to the user, in order to enhance possible recognition patterns [1]. This presentation is crucial in allowing users to take appropriate decisions in what concerns noise problems. Most of these can be successfully implemented in a GIS, using commonly available spatial analysis tools and operators. Some of the more useful alternatives, employing acoustic modeling are presented next. *Simple distribution analysis* is based on a selection of the sources of noise, which can be retrieved from the database. This uses a predicate which allows the selection of all relevant sources in a given neighborhood. *Simple concentration analysis* employs classification and neighborhood assessment functions which are used in order to produce the results. The concentration of noise-producing activities is presented in the form of a thematic map, based on some convenient spatial reference unit. *Global impact analysis* is conceived with the intention of showing, quantitatively, the impact of the accumulation of noise sources over an user-defined area. The previous descriptions can be conveniently expressed by means of an impact decay function $f\ (d,i)$. This function characterizes the degree of impact at a point located at a distance d from the original activity associated with the impact i. The total impact can be evaluated by means of function sum (Equation 1), and using the procedure outlined below.

$$I_p = \sum_{k=1}^{n} f\left(dist\left(A_k, p\right), i_k\right) \tag{1}$$

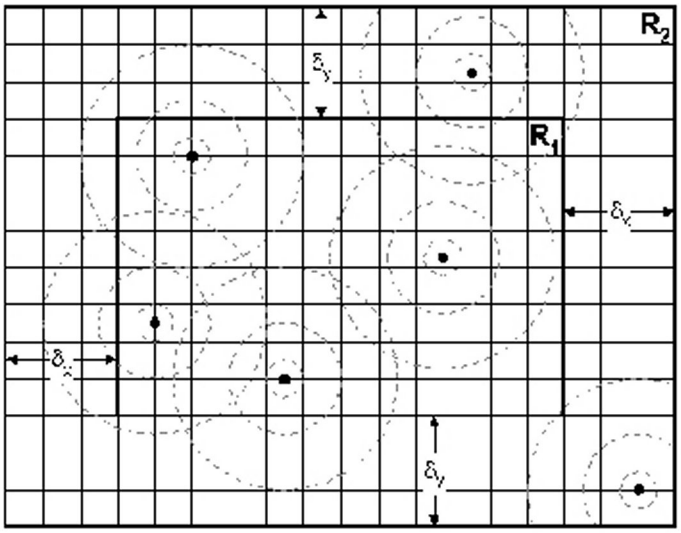

Figure 1: Example of area to be analyzed.

5 - TYPICAL CASE RESULTS

A typical set of results for an area inside the city of Belo Horizonte is shown in Figure 2 and Figure 3, representing the economic activities and traffic noise impact respectively. The analysis has then to consider the combined effect of the two parameters. The combination of the two parameters can then be used to establish the administrator decision making process.

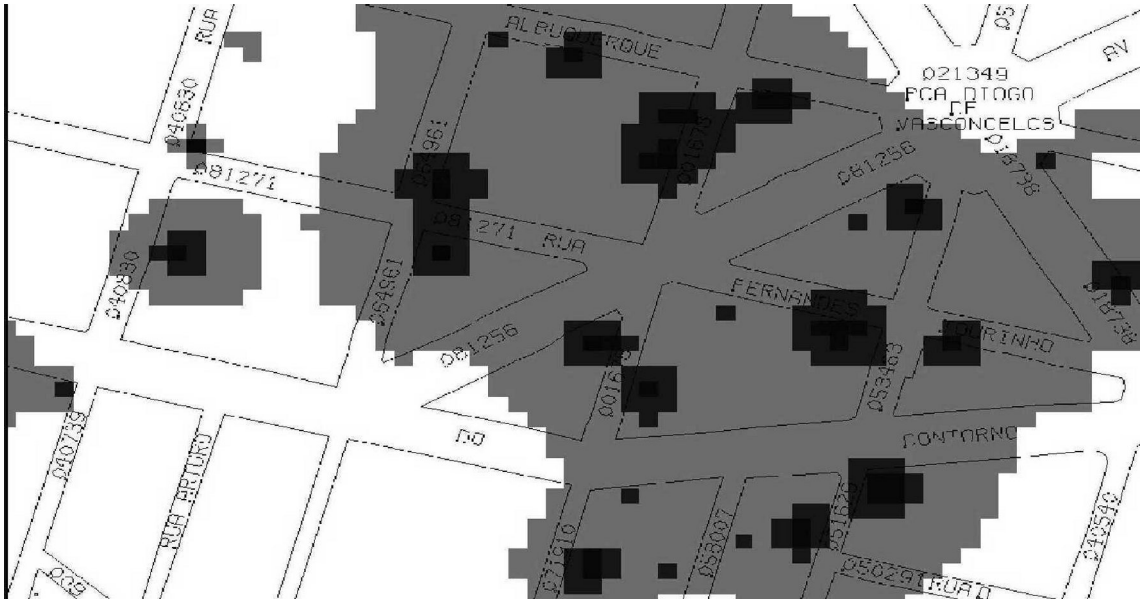

Figure 2: Typical fixed activity noise impact representation.

6 - FINAL CONSIDERATIONS

As a final word a more efficient model is now being developed with additional geometric and source complexities being introduced, including the use of a more efficient source definition, employing sound intensity levels.

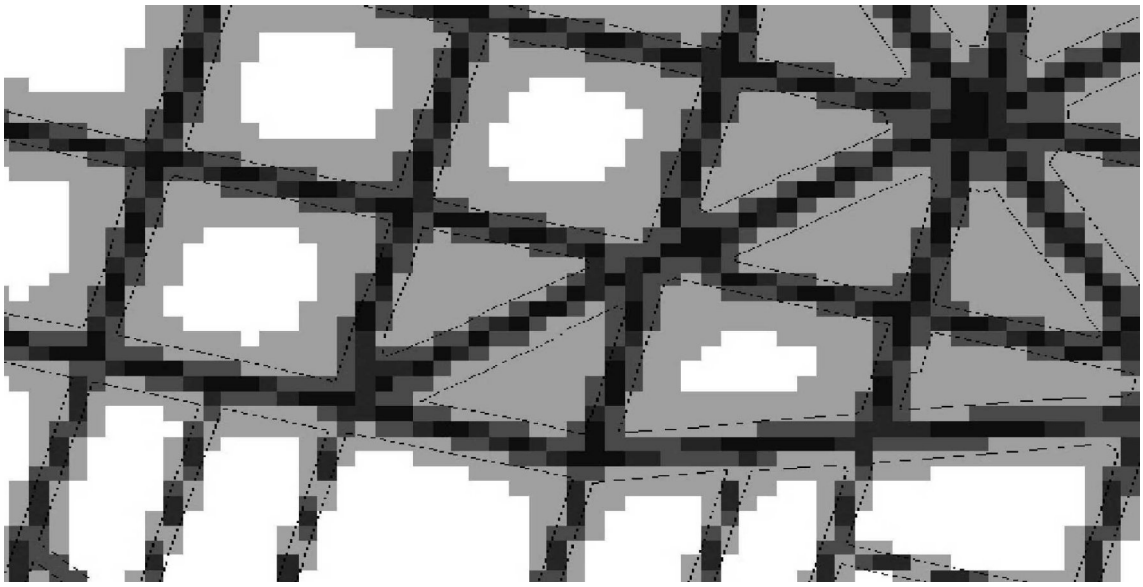

Figure 3: Typical traffic noise impact representation.

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