

A method of assessing measures to reduce road traffic noise: A case study in Santiago, Chile



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ABSTRACT

Road traffic noise is one of the major environmental issues affecting city dwellers' human health and well being in an urban environment. This study develops a method to assess measures to reduce traffic noise by modeling and quantifying its impact on the population near the main roads inside the urban perimeter. An iterative scenario projection process based on the interaction of a Geographic Information System (GIS) and a computational noise prediction module was proposed. Applying it to an actual case study in Santiago, Chile proved the applicability of the method. Several noise control measures were assessed including new road surfaces and traffic volume and speed reductions. The noise prediction model was able to simulate the effect of different action plans by combining single measures. Resulting noise levels at most exposed façades of 20 road corridors were assessed using two criteria: sleep disturbance at hospitals/clinics and noise limits by Chilean Technical Standard NCh 352. The method presented may be an effective tool to support authorities in their decision-making process concerning action plans to reduce road traffic noise.

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1. Introduction

Road traffic noise is one of the major issues affecting human health and well being in urban environments. It affects city dwellers' quality of life degrading residential, social and labor environments. The exposure to noise levels above 65 dB(A) entails adverse, accumulative and direct effects on human health such as auditory loss, sleep disturbance as well as cardiovascular and psychophysiological problems. Moreover, noise has socio-cultural, esthetic and economic costs [1].

In the city of Santiago, Chile, road traffic noise is the main source of environmental noise accounting for about 80% of total noise pollution. In 2001, 83.7% of its inhabitants lived or worked in areas where noise levels exceeded the threshold of risk of hearing loss. In some center districts, equivalent sound pressure levels (Leq) exceeded 80 dB(A) during daytime [2]. Nevertheless, this issue has received little attention by local authorities; there is a lack of an exhaustive inventory of grey areas and there is no documented environmental noise policy or specific road traffic noise regulations and abatement action plans. In this context, managing road traffic noise is a challenging task for urban planners and environmental authorities.

The development of a specific road traffic noise management strategy or noise action plan selection is a necessary part of a pro-active approach to environmental noise management [3]. According to SMILE [4], the implementation of control measures for traffic noise emission permits decreasing the global levels of noise pollution, thus reducing the environmental noise impact on the population.

Therefore, the objective of this study is to propose a method for quantitative evaluation of the effectiveness of measures to reduce road traffic noise. An iterative scenario projection process based on the interaction of a Geographic Information System (GIS) and a computational noise prediction module is proposed. Coelho and Alarcão [5], de Kluijver and Stoter [6], Hamed and Effat [7], Li et al. [8] and Pamanikabud and Tansatcha [9] have proven the efficacy of the combined use of noise prediction models and GIS to evaluate environmental noise by managing data, visualizing noise spatial distribution and quantifying their effects on population.

It is expected that the results of this study will contribute to improve the processes of strategic planning and decision-making for governmental authorities.

2. Method

The proposed method is based on a scenario projection process where GIS interacts with a noise prediction module as shown in Fig. 1.

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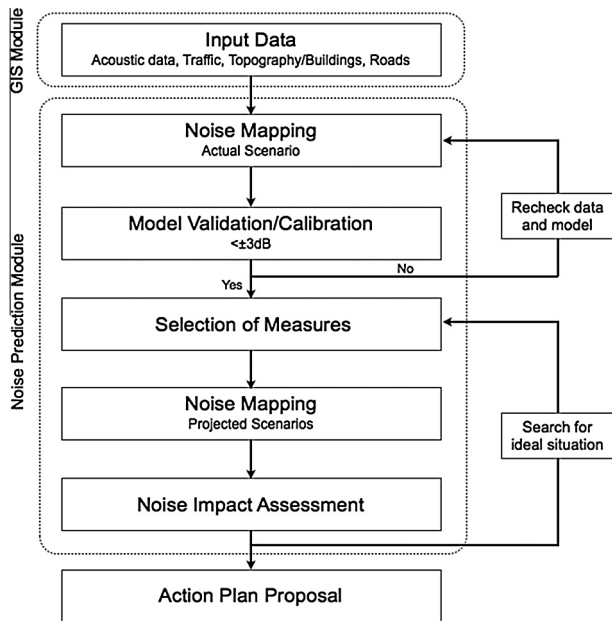


Fig. 1. Conceptual scheme of the proposed method.

2.1. Step 1: input data

Input data required by the noise prediction software is defined and the evaluation points are selected from the baseline information of noise levels. Roads and topography data are inserted into GIS to manage them as thematic layers. Non-spatial data such as noise levels, traffic flow and road surface are inserted into GIS as additional attributes.

2.2. Step 2: noise mapping, actual scenario

Geometric and acoustic models of each evaluation point are created in a sound prediction module. A 3D model of evaluation points is created; actual buildings are characterized with their spatial distribution, dimensions and coefficient of acoustic reflection depending on the materials of the most exposed façades. Road axes

are detailed according to width, number of lanes, surface and traffic sense. The maximum allowed speed and actual traffic flow defined as the number of vehicles per hour, segregating heavy and light vehicles, is also entered.

The noise prediction module generates contour noise maps of the influence area for the evaluation points corresponding to the base scenario, using L_d indicator, representative of daytime L_{eq} level in dB(A).

2.3. Step 3: model validation/calibration

The predictive model is calibrated using a linear regression analysis. Predicted noise levels in the exact location of the station measurement (defined as sidewalk receptor) are compared. The validity of the sound prediction is determined according to the range of ± 3 dB(A) proposed by Lee et al. [10].

2.4. Step 4: selection of measures

Road traffic noise control measures implemented in other cities are reviewed and selected according to their potential applicability to the city of study.

2.5. Step 5: noise mapping, projected scenarios

Scenarios associated to selected measures are projected. Single and combined measures are compared. The measure analysis is an iterative process based on the comparison of L_d levels of projected and base scenarios at the sidewalk receptor location.

2.6. Step 6: noise impact assessment

The assessment criterion for proposed measures depends on the risks associated with daytime road traffic noise exposure to inhabitants according to specific environments. In this study, noise levels at most exposed façades of residential and hospital buildings are assessed.

3. Results

The method was applied in the city of Santiago, Chile following the steps described above.

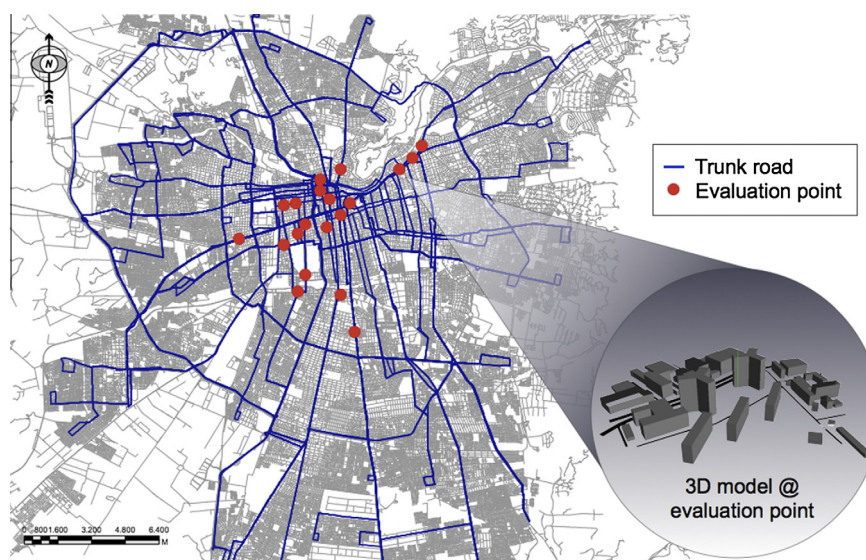


Fig. 2. Evaluation points and main trunk roads of Santiago.

Table 1
Selected measures according to noise emission control category.

Category	Measure description	Name
Traffic flow reduction	Reduction of 30% in the average light and medium weight vehicles daytime flow	R30
Speed reduction	Maximum speed limit of 40 km/h for heavy vehicles	V40
Road surface improvement	Current road surface improvement/ replacement	SP

3.1. Case study: input data

A baseline noise levels study developed by the Ministry of Transportation and Telecommunications [11] defined actual noise levels; this study registered equivalent sound pressure level on the main trunk roads of Santiago. The measurement stations were located on the sidewalk 2 m from the road at a height of 1.5 m above the ground. Twenty evaluation points were selected

corresponding to the five highest noise levels on five main avenues having at least one point of each public transportation category, according to the criteria used by SESMA [12]. SECTRA [13] defined the traffic flow of the main roads of Santiago. Traffic flow was defined as the number of heavy and medium/light vehicles per hour. Urban highways were not considered due to the low feasibility of noise control measures implementation on the source. In addition, three kinds of actual road surfaces were identified: asphalt, concrete, paving stones.

3.2. Case study: noise mapping, actual scenario

The acoustic and geometric models for the twenty evaluation points were generated as shown in Fig. 2. The standard RLS 90 was selected as a predictive standard due to the high correlation it predicts between measured and projected levels [10,14,15] and the penalty that this algorithm applies to the acoustic emission of heavy vehicles [16] which is coherent with the noise emission levels of Chilean public transportation.

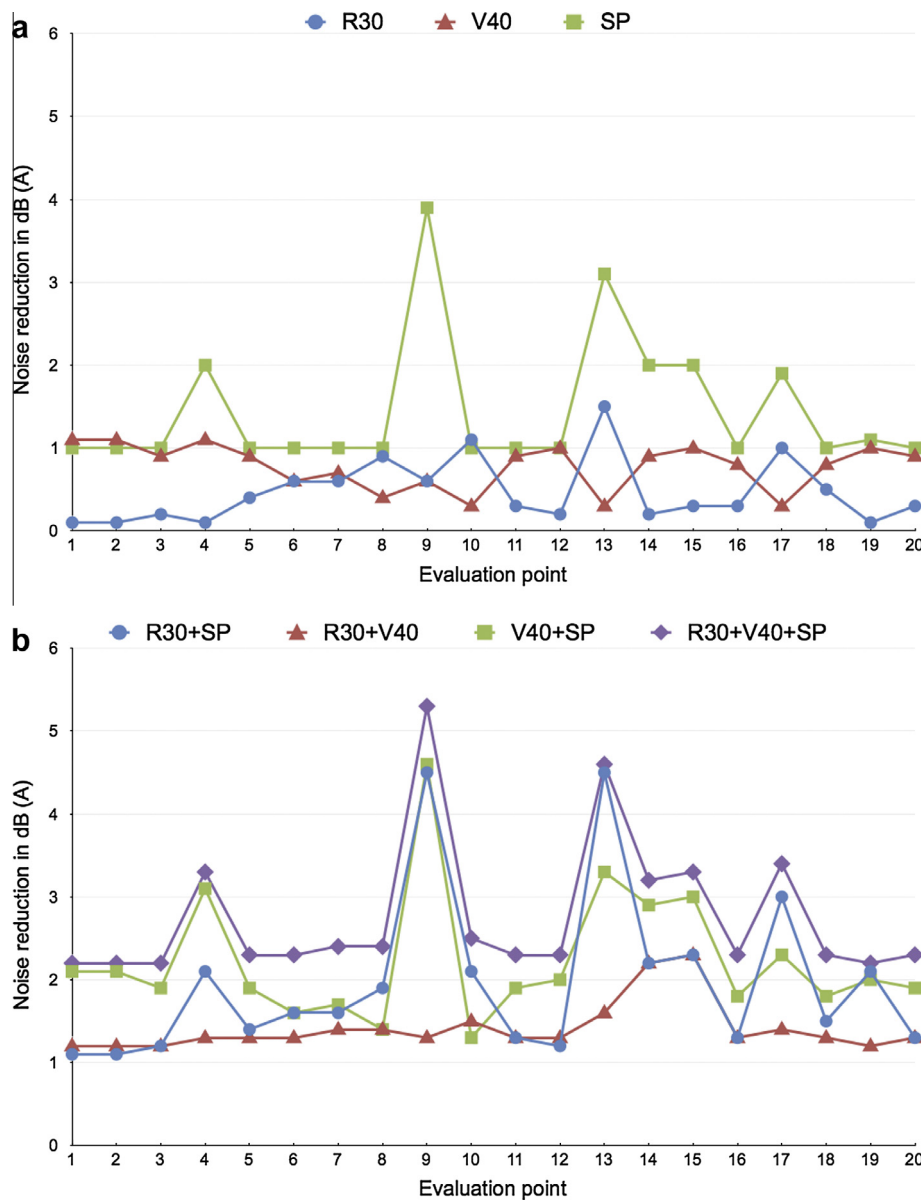


Fig. 3. (a) Single measures noise reduction and (b) combined measures noise reduction.

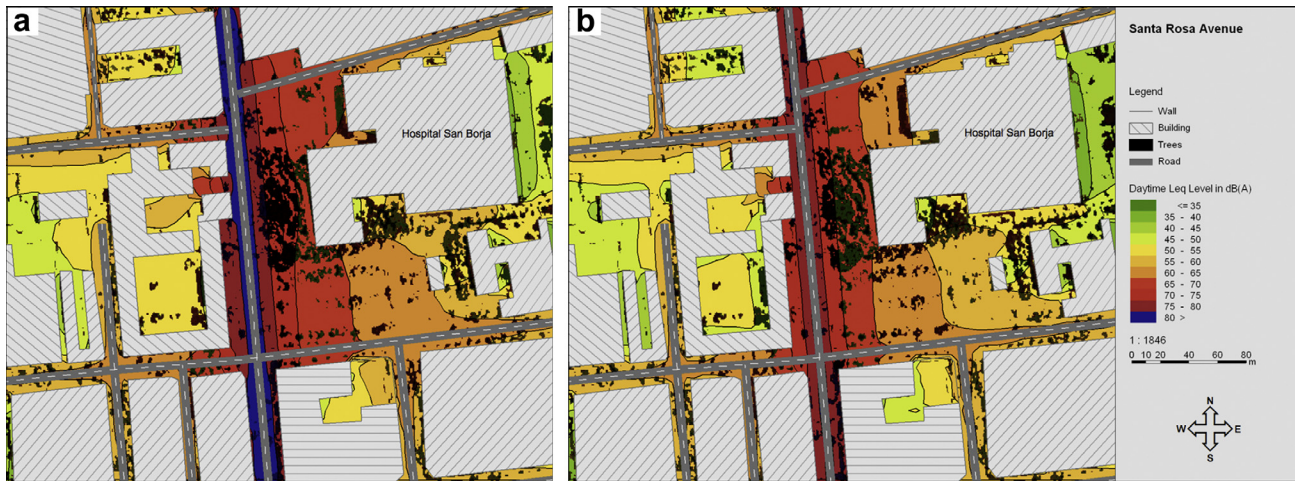


Fig. 5. Noise map at Santa Rosa Ave.



Fig. 6. Noise map at Vitacura Ave.

3.6. Case study: noise impact assessment

The effectiveness of R30 + SP, V40 + SP and R30 + V40 + SP scenarios was assessed in terms of inhabitant impact comparing daytime noise levels with recommended values for community noise at the most exposed façades of specific environments. In addition, the façades were categorized according to spatial location [19]; the most exposed façades in the first and second row were denominated A and B, respectively. Two assessment criteria were applied (a) habitability according to the Chilean technical standard NCh 352-1 [20] for the façades with actual residential use and (b) interference with sleep/recovery noise limits recommended by the World Health Organization [1] for hospital façades. Table 2 presents the noise limit levels according to each criterion. Standard acoustic building insulation of 20 dB(A) was applied.

Five first-row and thirteen second-row residential façades were identified at the evaluation points. The number of façades B is higher than façades A due to the fact that the evaluated areas include main roads where most exposed buildings tend to have commercial use. According to habitability criteria, there are no actual first row façades suitable for residential use in the evaluated areas. Proposed measures did not change this situation but did achieve avoiding noise levels over 80 dB(A) as shown in Fig. 4. The projected scenario achieved to reduce the impact increasing the total number of suitable second-row façades as shown in Table 3.

The impact of measures over noise sensitive receptors was assessed at hospitals façades. Noise sensitive receptors were defined for users of health facilities/buildings for whom the need of sleep and rest is critical for recovery. Two public hospitals and four private clinics were recognized at evaluation points. As in the case of residential receptors, most first-row façades in conflict in the base scenario did not vary their conditions after the projection of measures. This is due to the buildings being near the roads, thus the emission line. Nevertheless, after the projection of R30 + V40 + SP scenario there are no first row façades with noise levels over 80 dB(A) at any evaluation points. Noise contour maps comparing base with R30 + V40 + SP scenarios at two health facilities, Hospital San Borja located on Santa Rosa Avenue and Hospital Militar located on Vitacura Avenue, are shown as example in Figs. 5 and 6.

When considering the total number of façades, all the projected scenarios reduce the conflict cases of the base scenario. Scenarios that considered speed limits for heavy vehicles were the most effective reducing by 30% the number of façades in conflict.

4. Conclusions

The proposed method presents an alternative to the impact criteria for number of population affected displayed on large-scale strategic maps. This method based on scenario projections at specific evaluation points proves to be useful when large-scale census

data is not available. Moreover, considering actual building use over predefined land use enables differentiating the kinds of receptors in a specific evaluation area. This detailed evaluation delivers additional information to the obtained by the macro vision of strategic noise maps. This is particularly relevant for assessing the environmental noise impact over sensitive receptors. In addition, the proposed method gives an adequate framework for selecting, quantifying and assessing the impact over population for road traffic noise control measures thus constituting a support tool for decision-making processes concerning local action plans.

In the case study framework, it was possible to prove that the RLS-90 algorithm shows a good correlation between the measured and projected noise levels proving to be an adequate tool for road traffic noise prediction in the Chilean context. Specifically, projected scenarios with a speed limit of 40 km/h for heavy vehicles achieved a 30% reduction for the total number of façades in conflict according to noise thresholds recommended for most sensitive receptors.

Additionally, it was possible to eliminate actual road traffic noise levels over 80 dB(A) at all the evaluation points. The number of second row façades in conflict was reduced. Nevertheless none of the proposed scenarios could reduce the number of conflict cases in first-row residential façades. This fact suggests the need to include noise as a variable in land use planning processes and the need to create buffer zones to guarantee the acoustic comfort for the most sensitive receptors.

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