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Estimation of the acoustic screening effect of parked vehicles on urban streets by a BEM 3D model

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ABSTRACT

In situ measurements are usually used for the validation of strategic noise maps in accordance with that indicated by the Good Practice Guide. In this regard, the differences registered between the values of the sound levels measured in a city and those calculated using software may be due to several factors (incorrect estimation of vehicle speed, presence of sources not considered in the simulations, etc.). An aspect to consider in this line are the obstacles present in urban environments, which generate different effects in the propagation of sound from the source (road traffic) to the receiver microphones. In this paper, a study is carried out by means of numerical calculation in three dimensions with the Boundary Elements Method (BEM) of the acoustic shielding effect generated by vehicles parked on the sides of urban streets. Variations in the configuration of the parking lines are made to estimate the impact of these obstacles not usually considered in noise mapping.

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I-INCE Classification of Subject Number: 24, 30, 31.
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1. INTRODUCTION

Since the publication of the European Noise Directive [1], the use of strategic noise maps for the assessment and management of environmental noise is widespread, even in countries outside the European Union [2,3]. More recently, a modification of END establishing common methods of noise assessment (CNOSSOS-EU) [4] was published in order to standardize calculations performed in all countries so that they can be compared with each other. In connection with this topic, the END considers the possibility of calculating the sound indicators of noise maps by means of in situ measurements. However, it suggests the use of software for predictions. In the latter case, the Good Practice Guide [5] indicates that measurements are important for validating noise maps made using computational methods.

In this regard, some researches point out different factors that can be influential in the uncertainty of the results obtained for the sound indicators in the noise maps with respect to the measured values. First, Arana et al. report an uncertainty due to the software used [6] and the digital terrain model [7]. On the other hand, Can and Aumond highlight the influence of vehicle speed and acceleration [8]. Asensio et al. describe the uncertainty associated to the spatial sampling and interpolation processes [9]. Gómez et al. point out other sources of uncertainty such as vehicle type and establish relationships between urban variables and model uncertainties [10].

Some obstacles present in urban environments and not normally considered in computer models can also be a source of uncertainty between calculated and measured values. In this line of research, Montes et al. carried out a study through measurements in which they raised the possible existence of an acoustic shielding effect in urban streets due to the lines of parked vehicles [11]. This hypothesis was subsequently studied using a computer model using the Boundary Elements Method (BEM) in two dimensions [12,13]. The results show that these reflective obstacles can have an important effect on the calculated values for the sound indicators and that these can vary according to the urban configuration at the measuring point.

BEM is a method frequently used in the analysis of acoustic problems in outdoor environments [14,15]. However, two-dimensional models may present certain limitations in some cases. In this work, a study of the acoustic screening effect of parked vehicles on urban streets by a BEM 3D model is carried out taking into account the considerations of ISO 1996:1 and 1996:2 standards [16,17] and some aspects analysed in related studies [18].

2. METHODOLOGY

2.1 General description of the BEM 3D model

As indicated in previous section, a numerical model based on BEM was employed to analyse the effect of parked vehicles on the sides of urban streets over the sound level registered on building façades. A strategy using the Adaptive-Cross-Approximation with classic BEM was followed [19].

The propagation of sound in a three-dimensional space can be described in the frequency domain by the Helmholtz equation (Eq. 1):

$$\nabla^2 p + k^2 p = -\sum_{k=1}^{NS} Q_k \delta\left(\xi_k^f, \xi\right) \qquad \text{(Equation 1)}$$

If a point source is located within this propagation domain at X_0 (x0, y0, z0), the fundamental solution for the sound pressure at a point X can be defined as in Eq. 2:

$$G(\xi, X) = \frac{e^{-ikr}}{4\pi r} \qquad \text{(Equation 2)}$$

where: $r = \sqrt{(x - x_0)^2 + (y - y_0)^2 + (z - z_0)^2}$ and $\mathrm{i} = \sqrt{-1}$.

Considering perfectly reflecting plane surfaces through image-source method for planes z=0 m y x=0m, the corresponding Green's function can be written as Eq. 3:

$$G_{quarter}(\mathrm{x}, \mathrm{x}_0) = \frac{\mathrm{e}^{-\mathrm{i}kr}}{4\pi r} + \frac{\mathrm{e}^{-\mathrm{i}kr_1}}{4\pi r_1} + \frac{\mathrm{e}^{-\mathrm{i}kr_2}}{4\pi r_2} + \frac{\mathrm{e}^{-\mathrm{i}kr_3}}{4\pi r_3} \qquad \text{(Equation 3)}$$

where $r_1 = \sqrt{(x - x_0)^2 + (y - y_0)^2 + (z + z_0)^2}$, $r_2 = \sqrt{(x + x_0)^2 + (y - y_0)^2 + (z - z_0)^2}$ and $r_3 = \sqrt{(x + x_0)^2 + (y - y_0)^2 + (z + z_0)^2}$

Taking into account the Green's Second Identity, Eq. 10 can be converted into the classic boundary integral equation (Eq. 4):

$$C(\xi)p(\xi) = -i\rho\omega \int_{\Gamma} G(\xi, X) v_n(X) d\Gamma - \int_{\Gamma} \frac{G(\xi, X)}{\partial n} p(X) d\Gamma + \sum_{k=1}^{NS} Q_k G(\xi_k^f, \xi) \quad \text{(Equation 4)}$$

Once these conditions are set, the boundary must be discretised with NE_B elements and suitable interpolation functions within each element (constant interpolation in the present work) must be established to assemble a system with NE_B equations on NE_B unknowns. The solution of this system allows to get the values of the acoustic pressure and the normal velocity at each boundary element. Therefore, the pressure at any point of the domain can be obtained by applying the boundary integral (Eq. 4).

2.2 Analysis setup

In order to carry out the study, different aspects were taken into account to determine the analysis setup (Fig. 1). Firstly, totally reflective surfaces were considered for horizontal and vertical planes corresponding respectively to the urban ground and the façade of the buildings. Concerning the sound source, a succession of 40 point sources spaced 1 m from each other and at a height of 0.05 m above the ground was used to simulate traffic noise. These sound sources were placed at different distances from the park vehicles (d_{VS})

Receivers were placed on the façade (x=0 m) with a spacing between them of 0.2 m in both horizontal (y-axis) and vertical (z-axis) directions. In this way, a spatial average was made for each receiver height considering a 7.5 m wide central strip of the façade behind the parked vehicles.

Finally, regarding the configuration of the obstacles considered in this work, five vehicles with dimensions 4.5 m x 0.2 m x 1.5 m (length x width x height) and spaced 0.5 m between them were placed at different distances from the façade (d_{FV}). This configuration of the vehicles was made to ensure a shielding of the receivers with respect to the sound source of a minimum horizontal angle of view of 60º [17]. The surfaces of the vehicle were deemed fully reflective, while the wheels were ignored.

It should be clarified that a vehicle width of 0.2 m was considered for the calculations made in this work. This is due to the great computational cost for modelling a car by means of BEM 3D with a width close to real (1.5 m) for frequencies above 1000 Hz. Taking this aspect into account, some variations with respect to the real case are expected:

- a higher horizontal diffraction effect in the top of the vehicles than in the real case
- a lower acoustic shielding effect in the areas between parked vehicles for those sound waves with incidence angles on receivers different from 90º.

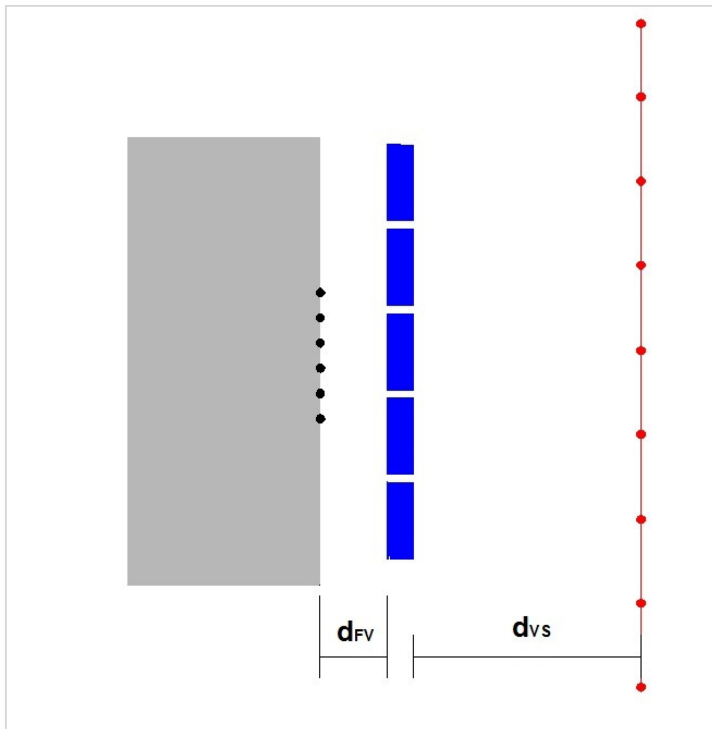


Fig. 1.- Analysis setup

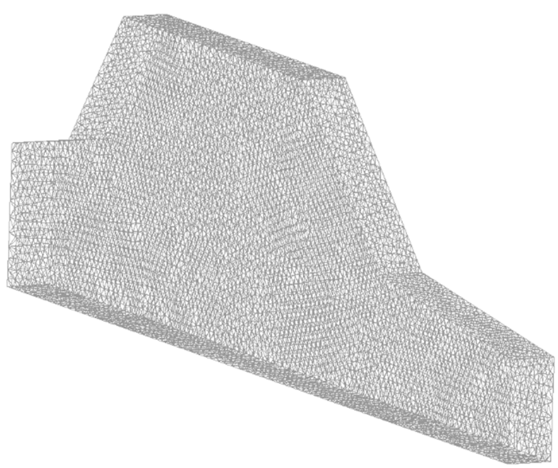


Fig. 2.- Discretisation of vehicle surfaces

3. RESUSTS AND DISCUSSION

Given the variety of urban street configurations in cities, it was considered of interest to make simulations for two different street typologies:

a) Narrow streets: d_{FV}=1.5m / d_{VS}=1.5m
b) Wide streets: d_{FV}=4 / d_{VS}=1.5m

Fig. 3 shows the broadband results in the frequency range 63-2000 Hz for the difference of the pressure level in dBA between the situations without and with parked vehicles depending on the height of receivers. Traffic noise spectrum was considered in the sound source. Frequencies higher than 2 kHz were not considered due to high computational cost.

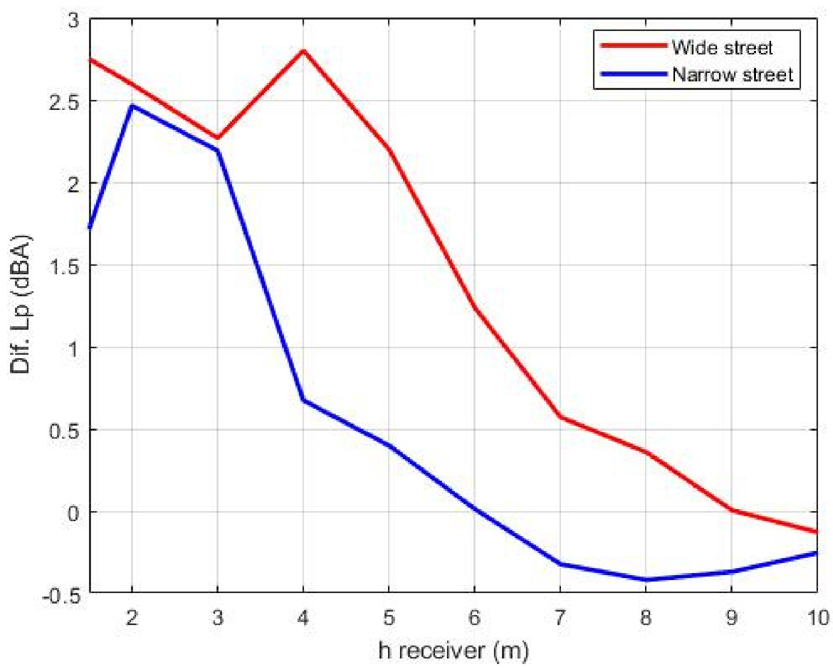


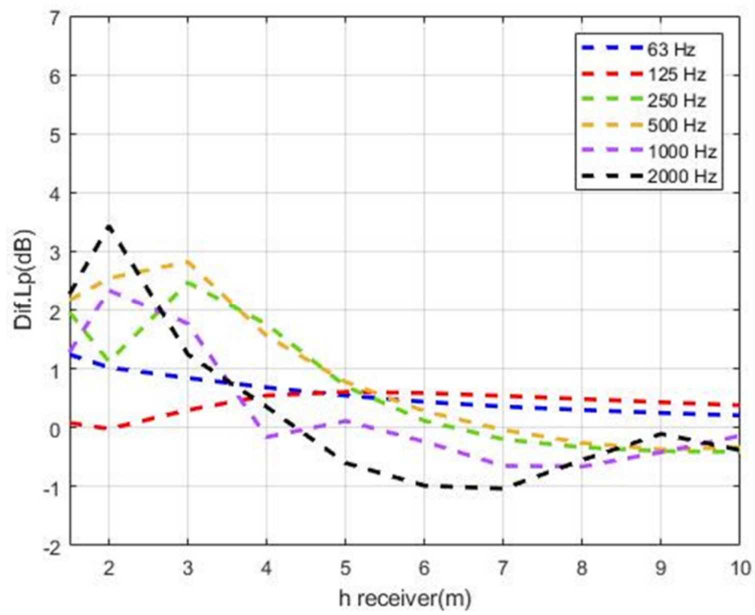
Fig. 3.- Broadband results for narrow and wide streets

A shielding effect due to vehicles parked on the sides of urban streets can be observed in Fig. 3 for the settings considered for narrow and wide urban streets. As expected, this effect decreases as the height of receivers increases. However, for the height of 4 m considered in strategic noise maps, values of the difference in levels of 0.7 dB and 2.8 dB in narrow and wide streets respectively are obtained. Even in the configuration established for wide streets, a value of 0.6 dB is detected at a height of 7 m.

The subject discussed in this work is interesting in connection with the validation phase of noise maps by in situ measurements. If these aspects are not considered, they can be a source of uncertainty between calculated and measured values. In this regard, it should be noted that the model considered narrow vehicles (0.2 m) as an approximation to the problem. In addition, simulations for the 4 and 8 kHz bands were not performed. For these reasons, the shielding effect is expected to be increased for a vehicle width close to a real case and a frequency range exceeding 2 kHz.

These settings were also studied for each octave band between 63 Hz and 2 kHz in Fig. 4. First of all, it can be pointed out that there is hardly any acoustic shielding effect due to vehicles parked in the 63 Hz octave band in neither of the two configurations. However, this effect becomes greater as frequency increases, especially in wide street configuration. As the sound source is located at the same distance from parked vehicles in both cases, this is probably due to the fact that in wide streets the vehicles are placed further away from the façade of buildings, so a wider area of acoustic shadow would be generated. The shielding effect obtained in 1 and 2 kHz bands is significant in the case of wide streets, where differences in sound levels of approximately 4 dB are obtained for receivers located at a height of 4 m above the ground.

a)



b)

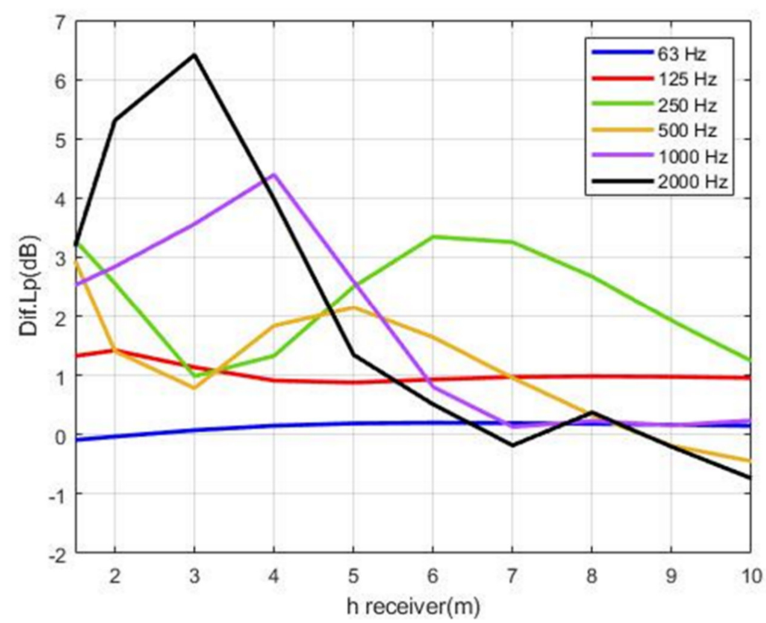


Fig. 4.- Octave band results for a) narrow and b) wide streets settings

4. CONCLUSIONS

This paper deals with the topic of the acoustic shielding effect of parked vehicles on urban streets by a three-dimensional BEM model.

Values for the difference in sound levels without and with parked vehicles of up to 2.8 dB are obtained in broadband analysis for receivers located at heights of 4 m in the configurations studied for narrow and wide urban streets. This screening effect is particularly noticeable in mid- and high-frequency octave bands, especially in the case of wide streets. As indicated in previous sections, the model can be considered as an approach to the problem. Therefore, the shielding effect is expected to be higher for a more realistic vehicle model and for the full frequency range between 63 Hz and 8 kHz.

This subject should be taken into account in the validation of strategic noise maps by in situ measurements to avoid introducing a source of uncertainty between calculated and measured values.

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6. REFERENCES

1. COM. *"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 L, 189. The European Parliament and the Council of the European Union, 0012–0026 (2012).

2. K.M. Paiva, M.R.A. Cardoso, P.H.T. Zannin. *"Exposure to road traffic noise: Annoyance, perception and associated factors among Brazil's adult population"*. Sci Total Environ, 650, 978-986 (2019).

3. A.M. Zytoon. *"Opportunities for environmental noise mapping in Saudi Arabia: a case of traffic noise annoyance in an urban area in Jeddah City"*. Int. J. Environ. Res. Public Health, 13, p. 496 (2016).
4. COM. "*Directive 2015/996 of 19 May 2015 establishing common noise assessment methods according to Directive 2002/49/EC of the European Parliament and of the Council"*. Official Journal L, 168. Brussels: The European Commission, 0001–0823 (2015).
5. WG-AEN (Working Group Assessment of Exposure to Noise). *"Good practice guide for strategic noise mapping and the production associated data on noise exposure"*. Version 2. European Commission, Position Paper 2 (2007).
6. M. Arana, R. San Martín, I. Nagore, D. Pérez. *"Using noise mapping to evaluate the percentage of people affected by noise"*. Acta Acust., 95, 550–554 (2009).
7. M. Arana, R. San Martín, I. Nagore, D. Pérez. "What precision in the digital terrain model is required for noise mapping?" Appl. Acoust., 72, 522–526 (2011).
8. A. Can, P. Aumond. *"Estimation of road traffic noise emissions: The influence of speed and acceleration"*. Transp. Res. Part D: Transp. and Env., 58, 155-171 (2018).
9. C. Asensio, M. Ruiz, I. Pavón, M. Ausejo, M. Recuero.*"Uncertainty in noise maps isolines: The effect of the sampling grid"*. Acta Acust United Acust, 97(2), 237-242 (2011).
10. V. Gomez Escobar, G. Rey Gozalo, J.M Barrigón, D. Montes González, P. Atanasio Moraga. "*Statistical attribution of errors in urban noise modelling"*. Appl Acoust. In press (2019).
11. D. Montes-González, J.M. Barrigón-Morillas, G. Rey-Gozalo. *"The influence of microphone location on the results of urban noise measurements"*. Appl Acoust.,90,64-73 (2015).
12. D. Montes-González, J.M. Barrigón-Morillas, L. Godinho, P. Amado-Mendes, G. Rey-Gozalo, P. Atanasio-Moraga. *"Selection of microphone location, measurement uncertainty and calculated noise maps"*. 24th International Congress on Sound and Vibration (2017).
13. D. Montes-González, J.M. Barrigón-Morillas, L. Godinho, P. Amado-Mendes. *"Acoustic screening effect on building façades due to parking lines in urban environments. Effects in noise mapping"*. Appl Acoust.,130,1-14 (2018).
14. C. Prieto Gajardo, L. Godinho, P. Amado-Mendes, J.M. Barrigon Morillas. *"Numerical analysis of acoustic barriers with a diffusive surface using a 2.5D boundary element model"*. J Comput Acoust,. 23(3) (2015).
15. F. Koussa, J. Defrance, P. Jean, P. Blanc-Benon. *"Acoustical Efficiency of a Sonic Crystal Assisted Noise Barrier". Acta Acust. united with Acust., 99, 3, 399-409* (2013).
16. ISO 1996-1. *"Description, measurement and assessment of environmental noise. Part 1: Basis quantities and assessment procedures"*. International Organization for Standardization (2016).
17. ISO 1996-2. *"Description, measurement and assessment of environmental noise. Part 2: Determination of environmental noise levels"*. International Organization for Standardization (2017).

18. J.M. Barrigón-Morillas, D. Montes-González, G. Rey-Gozalo. *"A review of the measurement procedure of the ISO 1996 standard. Relationship with the European Noise Directive"*. Sci Total Environ, 565,595-606 (2016).
19. L. Godinho, P. Amado-Mendes, P. Gil-Santos, M. Cordeiro. "*An efficient and accurate numerical model for the 3D analysis of sonic crystals*". 22nd International Congress on Sound and Vibration (2015).