How urban noise can be influenced by the urban form

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Abstract: _ The noise propagation is influenced by the behavior of the sound trajectory. The temperatures, the wind, the type of soil are other elements that influence the noise propagation. But the mainly causer of trajectory alterations are the barriers or the urban obstacles.

Therefore the study will allow monitoring the interaction of noise propagation effects in the studied urban forms.

Using urban indicators and a noise prediction model is possible to associated noise categories to urban façades forms.

The effects of noise in façades can be minimized in advance with the creation of different scenarios and foresee in a preliminary phase the most exposed façade to a higher noise level.

Key-Words: _ Urban Noise, Urban Form, Urban Indicators, Noise Indicators

I. INTRODUCTION

THE study of the interaction between sound sources and the urban form is the main goal of this work, as well as its influence in a certain sound environment. Its objective is to study and characterize the theoretical and conceptual bases of phenomena related to emission and propagation of noise. Furthermore, to apply computerized simulation models related to the emission and propagation of noise and identify the several quantitative indicators of form and dimension of the urban form as a way to suggest a model for quantitative evaluation of urban form typology, regarding the different quantitative indicators of form.

II. DEFINITION AND CARACTERIZATION OF URBAN FORM TYPOLOGIES

The conception of urban typologies concerns to arrangement, appearance and functionality of cities and, especially, to conception and use of public urban space.

A. Quantative Indicators of Urban Form

Trying to characterize the urban form is, in spite of the growing interest, an exploration of real differences that in a rigorous and exhaustive form is illustrated in incipient studies.

The indicators that we intend to study have a dimensional nature. Although they are based on studies from different authors, they are urban indexes and spatial metrics that can be applied to other typologies with external specificities from the presented models.

The metric space is a concept that generalizes the idea of geometric distance. A set in which there is a metric or scale, whose base is similar and it is easy to compare. This can be detected in the present study and after presenting the following indicators to be used.

a) Urban Indexes

The urban indexes are multipliers that we can apply either to an area or to an reference surface or to an intervention area with the possibility to built.

Occupation Index or Rate of Soil Occupation (% P) - is the indicator that relates the quotient between the surface of deployment and the land area represented in Fig. 1.

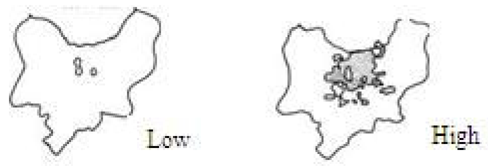

Fig.1. Illustration of Occupation Index (%)

The calculation of the Occupation Index (% P) is presented by Equation 1:

$$\%P = \frac{A_{imp}}{A_t} \quad (1)$$

Meaning:
A_{imp}.: Surface of deployment, [m^2];
A_t : Total Area, [m^2].

The urban form that has the largest area of implantation will have the higher content (% P).

Volumetric Land Index (Iv) - The indicator of Fig. 2 represents the entire space above ground, corresponding to all the buildings that exist or can be made in a building, except the elements or protrusions only with decorative purposes or the technical facilities and fireplaces. But this indicator includes the roof volume, expressed in cubic meters (m3).

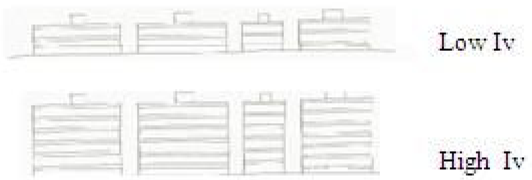

Fig.2. Illustration of (Iv) variation and of the relationship of number of floors

To calculate Volume Index of construction (Iv) we use Equation 2:

$$Iv = P x\ N x\ H \quad (2)$$

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Meaning:
P: Surface of implantation, [m^2];
N: Number of floors, [-];
H: Floor height, [m].

Thus the urban form that has the most floors will have a highest value of Iv.

b) Spatial metrics

Landscape metrics listed below, are employed through the use of quantitative indices representative of the physical features of urban form type and study subject [5].

In the present study we will use the following quantitative urban indexes: Compactness Index and Index of porosity or permeability.

Compactness Index (CI) -This indicator measures not only the shape of the urban area (urban patch), but also considers the global urban landscape fragmentation [7]. The Fig. 3 illustrates the relationship between the urban form and regularity of fragmentation and its influence on the CI.

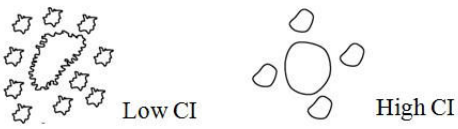


Fig.3. Illustration of the forms regularity variation that influence the index (CI)

The Compactness index (CI) is calculated based on de next equation:

$$CI = \frac{\sum_i \frac{P_i}{p_i}}{N^2} = \frac{\sum_i 2\pi\sqrt{\frac{s_i}{\pi}}/p_i}{N^2} \qquad (3)$$

Meaning :
s_i : Patch area, [m^2];
p_i : Patch perimeter, [m];
P_i : Perimeter of a circle with the area of s_i [m];
N : Total number of Patches, [-].

An urban area has higher values of CI for more regular and more compact urban forms.

Porosity Index (ROS) - is the permeability indicator which measures the proportion of open space, compared to the total urban area. Fig. 4 illustrates the relationship of the area of open space and total occupied area and its influence on ROS.

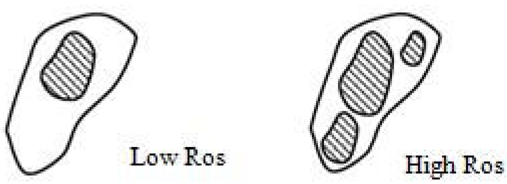


Fig.4. Illustration of the variation of open space with the total area that characterizes the index (ROS)

The Index of Porosity or Permeability is calculated by Equation 4 shown below:

$$ROS = \frac{s'}{s} x\, 100\ \% \qquad (4)$$

Meaning:
s': Summarization area of all the "holes" within the urban area, [m^2];
s : Summarization area all patches, [m^2].

An urban area has higher levels of ROS to urban forms with higher open spaces. This indicator is also called as the ratio of open spaces.

Complexity of the Perimeter Index (Fractal) - The complexity is defined by the perimeter fractal dimension. This index describes the complexity of the perimeter of an urban area through the relationship between perimeter and area [1], [12].For research we used the average fractal dimension of urban patches weighted by the area (Equation 5).

The value of fractal dimension is between 1 and 2. Lower values are obtained when the patch has a simpler form (the fractal dimension of a circle is equal to 1).If the perimeter is more complex and irregular; fractal dimension is greater (Figure 5).

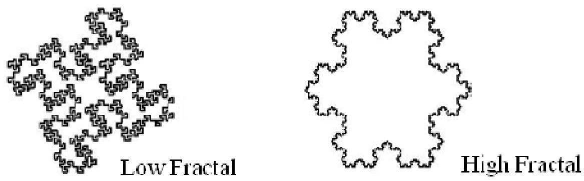


Fig.5. Illustration of the forms regularity and complexity variation that influence the index (Fractal)

The Fractal index (*fractal*) is calculated based on the next equation:

$$fractal = \sum_{j=1}^{n} \left(\left(\frac{2\ln\left(\frac{p_i}{2\sqrt{\pi}}\right)}{\ln a_i} \right) \left(\frac{a_j}{\sum_{j=1}^{n} a_j} \right) \right) \qquad (5)$$

Meaning:
p_i : Patch perimeter, [m];
ai = Patch area, [m^2];
aj= Total area, [m^2];
n = Total number of Patches, [-].

B. Theorical Model Neighbourhood Proximity

The mathematical expressions referenced previously will be applied to types of urban forms, presented in a theoretical model, the “Neighborhood Proximity Model “of João Branco Pedro [10].

Neighborhood proximity means a residential unit functionally and spatially organized around an outdoor space, where neighborhood residents tend to establish relationships. The sample, which funded this typological classification, was developed by João Branco Pedro [10], in which the immediate neighborhood typologies were defined according to two perspectives:

❖ The programmatic perspective, which is defined as sets of neighborhoods proximities, with identical functional programs (such as the number of houses, the number of habitants or similar occupation index);

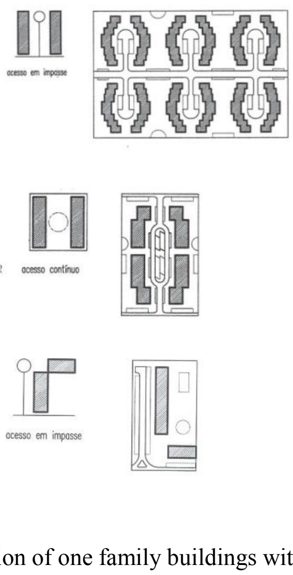
❖ The morphological perspective, it is meant as a set of neighborhoods proximities, with similar formal characteristics (such as the form of implementation of the set of buildings, the form of buildings in relationship with the streets, the form of local access road, the number of floors above the main entrance of the buildings of neighborhood proximity or the number of habitation from neighborhood proximity).

a) Requirements Applicable to Project Areas of Neighborhood Proximity

At this stage, we present the design parameters applicable to each of the spaces that compose the neighborhood proximity. That is, the circulation spaces, the buildings and unbuilt spaces, which are listed below.

The road system includes the minimum road hierarchy, the minimum width of the track, and the minimum impermeable components of the infrastructure. The residential Lots include the maximum height of buildings and the minim distance between the facades. The Green space, on the other hand, contemplates the minimum area of the Lots' minimum area.

Therefore, and based on the articulation of these spaces, roads, housing and green, was chosen for the following types of linear deployment, as shown in Fig. 6.



(a)

(b)

(c)

Fig. 6.Ilustration of one family buildings with two floors (a), 4 floors multifamily (b), with 8 floors multifamily buildings(c)

The Selected models are intended to diversify the sample, so it can be listed the different effects of noise propagation on the composition. Accordingly, the proposal aims at models with concavities, convexities and a linear model with the absence of saliencies. Thus, it is expected to obtain comparative results and to present some conclusions on how the urban form may influence the propagation of urban noise.

III. URBAN NOISE

It is understood by noise an unpleasant sound or of annoyance for human beings. The concept of noise is defined as the variation of atmospheric pressure, within the limits of the range and frequency band to which the human ear responds. Since the human ear is more sensitive to certain frequencies than others, the level of disturbance is dependent on the spectral content of noise. The perception of noise depends on the people, moments and places. That is why it is difficult to determine objectively the awkwardness of it.

The environmental noise of urban environment, whatever the location is not stationary, it varies in time, which appears in the signal produced by peaks and breaks. When you want, for example, to characterize the noise generated by road traffic since its noise oscillates; a simple metering of its value is not enough. It will be necessary to calculate an average, obtained after measuring for a representative period of time, as well as indicators that can reveal the maximum and minimum peaks which occurred during the measurement time, as intended to be made in the following typologies.

In agreement with the established in Portuguese Legislation [3], the acoustic zoning map classifies the land in two classes: "sensitive areas", which have allocated existent or foreseen residential uses, as well as schools, hospitals, recreation and leisure; and "mixed areas", which overlap the uses of sensitive areas plus other ones like retail shops and services, parking, etc.. This legislation forces the consideration of outdoor noise levels in the planning process, namely in the elaboration of zoning plans. According to the provisions of the law, sensitive areas may not be exposed to an equivalent continuous sound level in all day-time (A-weighted average sound level – Lden(A)), higher than 55 dB(A) and 45 dB(A) in night-time (period between 9.00 p.m. and 7.00 a.m., Ln(A)); and mixed areas may not be exposed to a Lden(A) higher than 65 dB(A) in all day-time and 55 dB(A) in night-time.

Traffic noise levels can be evaluated by two different means: measurements and prediction. The measurement method is only feasible when applied to existent situations; the prediction methods are used with advantage from the very start of the planning process to the final detailed design of noise abatement measures.

The noise prediction method should provide secure results, which represent the real situation of noise levels under any conditions of emission and propagation [9]. Achieving this depends on the assessment of noise emissions due to traffic flow and assessment of noise attenuation between the source and the receiver.

Prediction methods have proved to be very useful and applied in a wide range of noise situations. When a calculation method is used, a large number of scenarios can be greeted by introducing different traffic flows, several types of pavement, variable number of reception points, and noise abatement measures designs. By contrast, measurements results give information only about a very limited situation (the specific traffic and weather condition at the time the measurements are made).

There are available in the market numerous prediction noise models, which constitute an important toolbox in the simulation of the acoustic situation, as referred by Bertellino and Licitra [2].

The model adopted for this research, named New Method of Forecast of the Traffic Noise (NMPB 96) was developed in France in 1996. It is the method recommended by Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 [4], relating to the assessment and management of environmental noise [13].

IV. THE INFLUENCE OF URBAN FORM ON THE PROPAGATION OF URBAN NOISE

The combination of typologies and indicators presented previously served as the basis for the development of nine different scenarios, as a base comparable to the analysis that we intend to study.

Thus, the urban forms submitted (Type 1, Type 2 and Type 3) are based on a grid of 210mx140m, with a total area of 29 400 m2 and a perimeter of 700 m.

Each of the scenarios developed is served by two local distributor roads and local access roads. For this calculation was only included in the assessment, the local distributor roads. The roads considered in each scenario developed, possess the following characteristics:

- asphalt pavement without slope;
- fluid flow of road traffic (300 total vehicles / h with 5% heavy);
- velocity of 50 km / h.

For the evaluation of noise levels at the facades, we developed a square grid calculation over all the facades of 1.5 m x 1.5 m and a distance from the facade of 0.5 m. The number of floors of buildings is variable (2, 4 and 8 floors) with a ceiling height of 3m, ground floor inclusive.

V. RESULTS

The combinations of the different parameters mentioned above are reflected in the following illustrations (Fig. 7, 10 and 13):

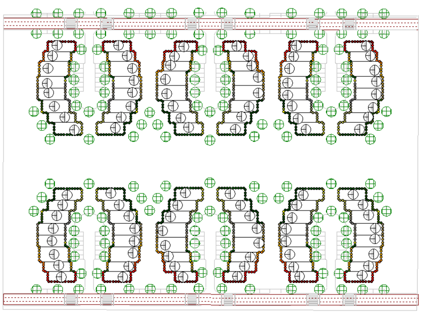


Fig. 7. Illustration of Form Type 1

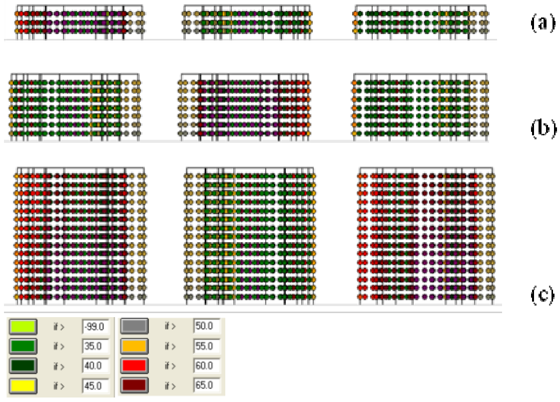


Fig.8. Location of the nodes evaluation in buildings with form Type 1, with two floors (a), 4 floors (b) and 8 floors (c)

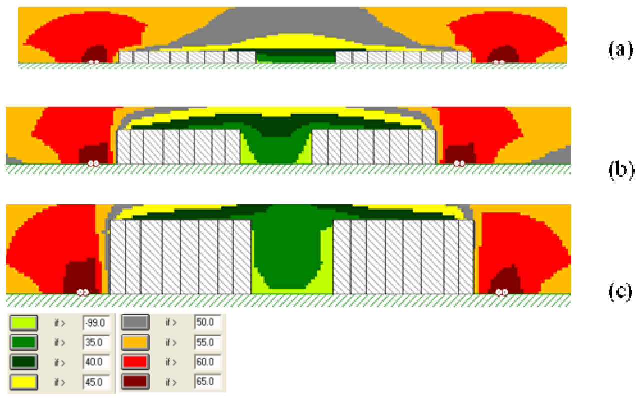


Fig.9. Vertical noise Map form Type 1, with 2 floors (a), 4 floors (b) and 8 floors (c)

The relationship of variation in the number of floors, with the effects of noise propagation in different facades is illustrated and was quantified, and its results are in Table 1.

As can be seen in Table 1, there is a slight reduction in Leq, with the increase in the number of floors for maximum and average values. In the case of the minimum values of Leq, this trend is reversed. Fig. 9 illustrates the form of sound waves from the source and how it affects the most exposed facades. As the number of floors increases the extent of the most exposed façade also increases, increasing the average and maximum Leq. On the other hand, with increasing high the size of the protected area increases too, causing a reduction in the minimum Leq.

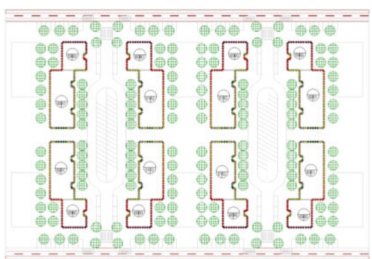


Fig.10. Illustration Form Type 2

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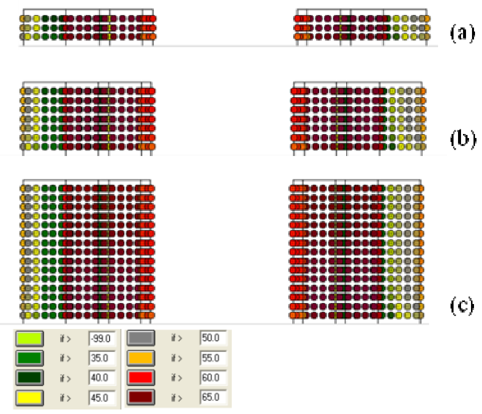

Fig.11. Location of the evaluation nodes in buildings with Type 2 form, with two floors (a), 4 floors (b) and 8 floors (c)

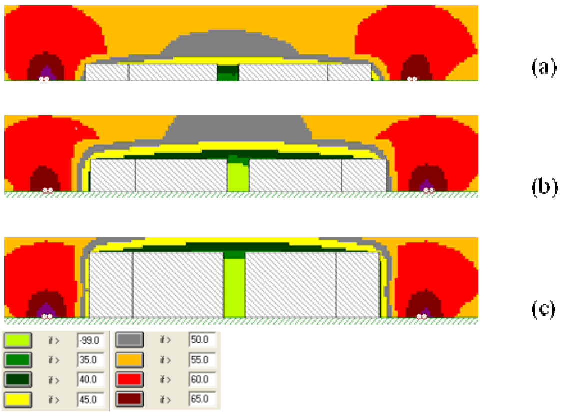

Fig.12. Vertical Noise Map from Form Type 2, with two floors (a), 4 floors (b) and 8 floors (c)

As in the previous case, there is a slight decrease of Leq with increasing of the number of floors in the case of maximum and average values. In the case of the minimum values of Leq, this trend is reversed. Fig. 12 illustrates the form of sound waves from the source and how it affects the most exposed façades. The analyses to be made, of the obtained results, are in accordance with the above analysis (Form Type 2).

Studies on previous forms contemplated concavities and convexities in its formal composition, the Type Form 3 that is presented below and illustrated in Fig. 13, is a pure composition, without corners that can create additional changes in the propagation of the noise waves.

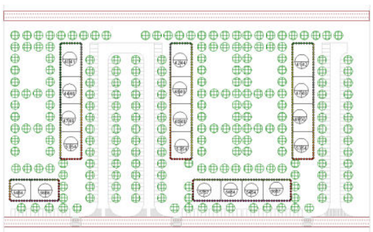

Fig.13. Illustration of Form Type 3

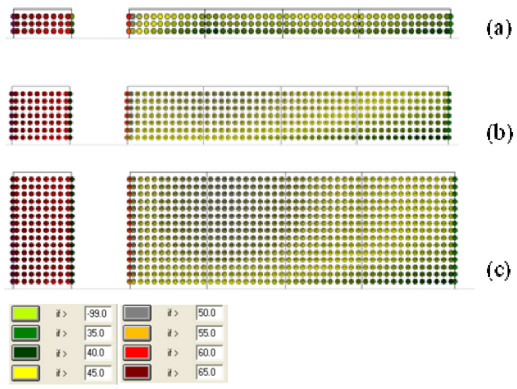

Fig.14. Location of the evaluation nodes in buildings with Type 3 form, with two floors (a), 4 floors (b) and 8 floors (c)

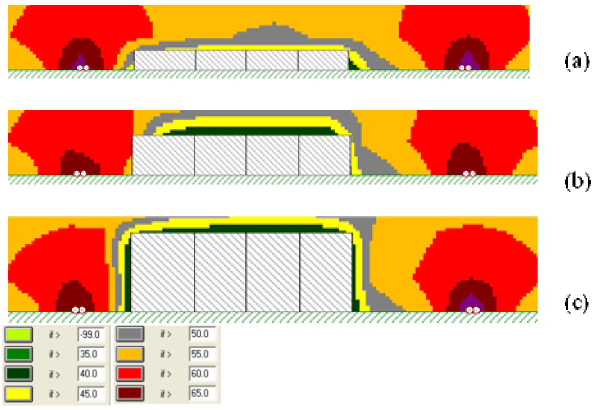

Fig.15. Vertical Noise Map from Form Type 3, with two floors (a), 4 floors (b) and 8 floors (c)

The relationship between the obtained noise level in the façades and the number of floors in the Form Type 3 is similar to the one obtained in the Forms Type 1 and Type 2. The average values of Leq will increase as the number of floors increases. Inverse tendency is find for maximum values of Leq.

VI. CONCLUSIONS

This study intended to approach the influence of urban form in urban noise propagation. This interaction was evaluated by calculating urban indicators, which measure urban form and noise levels on the façade. Nine scenarios were considered with three urban forms and with several floors level (2, 4 and 8 floors).

The indicators of urban form and noise for the nine developed scenarios are summarized in Table 1.

As can be seen in Table 1, in the three urban forms, there is a small decrease of Leq with increasing the number of floors (i.e. Volumetric Index Iv), for maximum and average values. In the case of the minimum values of Leq, this trend is reversed. As illustrated in Fig.s 9, 12 and 15, the form of sound waves from the source, being cylindrical, influence, in different ways, the most exposed façades. As the number of floors increases, the extent of the most exposed façade also increases, increasing the average and maximum Leq.

TABLE 1. RELATIONSHIP BETWEEN URBAN FORM AND NOISE

		Form Type 1			Form Type 2			Form Type 3		
Nº Floors		2	4	8	2	4	8	2	4	8
I_v [m^2] x10^{-3}		47.8	95.6	191.3	32.6	65.2	130.4	20.2	40.6	81.2
% p		27.1			18.5			11.5		
CI [-]		0.05			0.11			0.31		
ROS [%]		73.0			82.0			89.0		
Fractal		1.15			1.15			1.13		
LeqA [dBA]	**Min.**	37.0	36.6	36.4	34.7	34.0	33.5	46.6	46.6	46.5
	Average	49.1	49.1	49.6	50.6	51.1	51.1	59.0	59.0	59.1
	Max.	54.6	54.7	55.1	59.0	59.1	59.1	58.2	59.1	59.1

In contrast, with increasing number of floors, the size of the protected area increases causing a reduction in the minimum Leq.

With increasing Porosity or Permeability Index (ROS), the average values of Leq also increase, this is explained by the fact that the greater the permeability of the urban form is the sound waves more easily are able to reach the buildings inside.

With the increase of the Compactness Index (CI), medium values of Leq also increase. This is due to the fact that the greater the regularity of urban forms, the lower is the possibility of formation of shadow zones, that is more protected areas.

Regarding to the Occupation Index (p), when decreases it generates façades with higher noise levels. The more "occupied" the soil, the more obstacles exist and therefore the greater the possibility to form protected areas.

Concerning the Fractal Index, the variation obtained is consistent with the variation of facades noise levels. The Fractal Index mainly describes the raggedness of the urban boundary. The higher this value is, the more irregular the shapes are. This fractal dimension approaches one for shapes with simple perimeters and approaches two when shapes are more complex. Is expected an indirect correlation between Fractal Index and facades noise levels. The regularity of urban forms decreases the possibility of formation of shadow zones that is more protected areas.

The relationship between noise and urban form intent to promote the creation of protected areas or shadow areas in urban context, as one of the objectives of this study.

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