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Study on the weighting of building acoustics descriptors and their influence on the quality of acoustic comfort for the occupants

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Summary

It was recently created in Portugal a methodology for residential building acoustics classification. This methodology takes into account three levels of evaluation, being one of them, the dwelling. To evaluate the dwelling are considered eight descriptors which are weighted by specific coefficients in order to establish a differential influence of each descriptor in the dwelling's final evaluation score.

This paper focus on a detailed analysis on the reliability of these weighting coefficients as values that are supposed to reflect the population complains related to the various types of sounds (neighboring; external; equipment) they are exposed to, and so that on which descriptors have more or less influence in the acoustic comfort provided by the dwelling. The magnitude of these coefficients was studied and obtained through a social survey, conducted using a fill tool on-line. Based on the obtained results, it was possible to define a set of adequate values for these coefficients, and thus compare them with the ones established on the acoustic evaluation scheme for residential buildings existing in Portugal.

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1. Introduction

In the past few years it has been observed a major development with regard to the sustainability of buildings in all its aspects, one being the acoustic performance. In this field, one of the goals is to create a system of acoustic classification for residential buildings, the most complete and simple as possible, allowing its easy use by professionals as well as its understanding by consumers. It's in this context that, in Portugal, was developed a method of acoustic classification for residential buildings.

In this paper are studied the coefficients defined in this acoustic evaluation and classification scheme. These coefficients are used to differentiate the weight of descriptors considered in the assessment of the dwelling.

2. Portuguese scheme for residential building acoustics classification

In Portugal, it was recently created an acoustic evaluation and classification scheme for residential buildings. This scheme[1], edited by the National Laboratory for Civil Engineering (LNEC), takes into account three levels of evaluation: the building's environment, the building itself (common accesses) and the dwelling.

As the dwelling's evaluation concerns, and in accordance with Portuguese Buildings Acoustics Code [2], eight descriptors are considered for the purpose, to which a score is given according to their value (figures 1-3). In figures 1 (airborne type) and 2 (impact type and noise level of equipments) are shown how the points are attributed in function of the measured value for the descriptors, being R a reference to legislative requirement. Figure 3 shows the points distribution for the eighth descriptor [3]. The eighth descriptor, which concerns the airborne insulation between living rooms and bedrooms of the same unit, is not covered by Portuguese legislation.

These descriptors, as shown in Table I, are weighted by specific coefficients in order to establish a differential influence of each descriptor in the dwelling's final evaluation score according to equation 1.

The discomfort caused on people exposed to different types of sounds is not the same, so, it is not expected that various types of sounds have the same weight for the classification of the acoustic performance of a dwelling. The need to distinguish the sound insulation's influence in the dwelling's acoustic performance leads to the introduction of weighting coefficients in the classification scheme.

$$Dwelling = \sum_1^N \alpha_i P_{ti} / \sum_i \alpha_i \qquad (1)$$

N - Number of descriptors considered;
$\mathbf{P_{ti}}$ - Score given according to their value;
$\boldsymbol{\alpha_i}$ - Weighting coefficient.

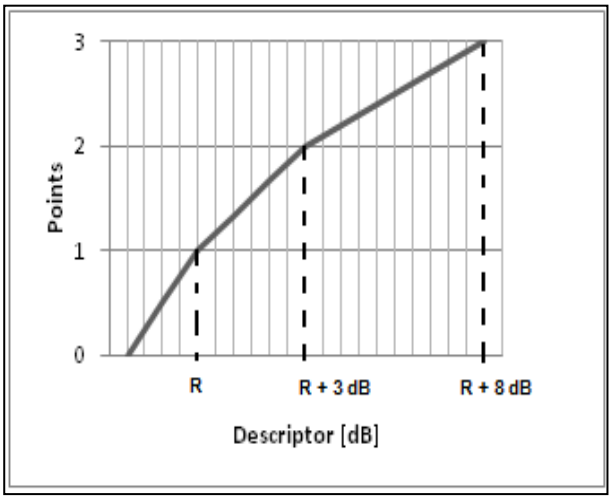

Figure 1. Average points according to descriptor's value of airborne insulation

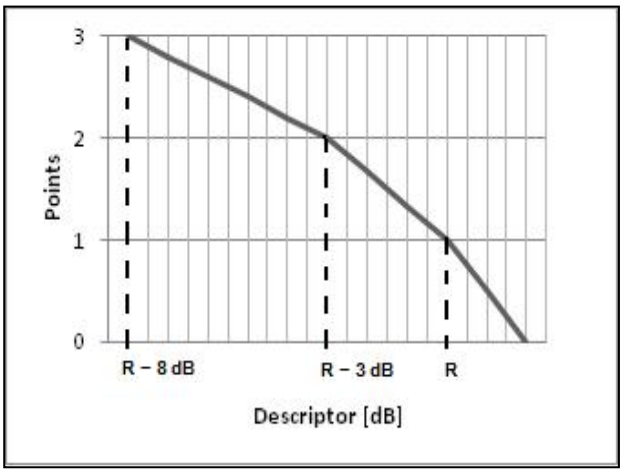

Figure 2. Average points according to impact insulation descriptor's value also apply to noise level from equipment descriptor's value

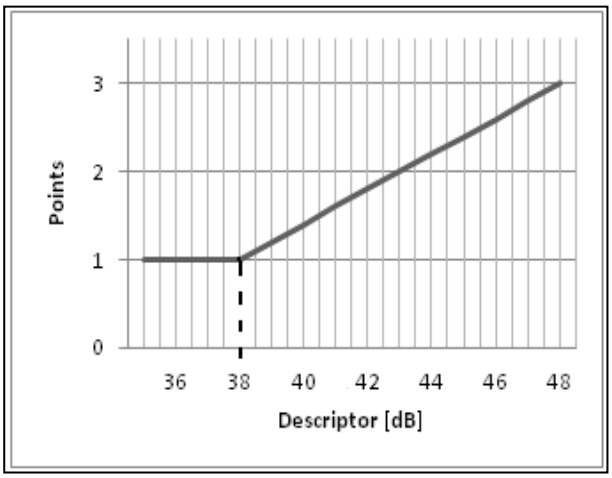

Figure 3. Average points according to descriptor's value of airborne insulation between living rooms and bedrooms of the same apartment or unit

Table I. Descriptors and weighting coefficients

Descriptor	Symbol	Weighting coefficient
1.Airborne sound insulation (living rooms and bedrooms)	$D_{2m,nT,w}$	$\alpha_1 = 4$
2.Airborne sound insulation (between rooms of emission apartment and living rooms and bedrooms of reception apartment)	$D_{nT,w}$	$\alpha_2 = 6$
3.Airborne sound insulation between common accesses as emission places and living rooms and bedrooms or reception apartment	$D_{nT,w}$	$\alpha_3 = 2$
4.Airborne sound insulation between bedrooms or living rooms (as reception spaces), and adjacent spaces used for commercial, industry, services or entertainment (as emission places)	$D_{nT,w}$	$\alpha_4 = 8$
5.Impact sound insulation in bedrooms or living rooms (as reception spaces), due to impact sound exerted on other apartment floors or on common accesses (as emission spaces)	$L'_{nT,w}$	$\alpha_5 = 8$
6.Impact sound insulation in bedrooms or living rooms (as receptions spaces), due to impact sound exerted on floor of adjacent spaces used for commercial, industry, services or entertainment (as emission places)	$L'_{nT,w}$	$\alpha_6 = 6$
7.Noise level from equipment such as lifts, water supply systems, garage doors, ventilation, waste water, pumps, cooling, etc., within bedrooms or living rooms	$L_{Ar,nT}$	$\alpha_7 = 5$
8.Airborne sound insulation between living rooms and bedrooms of the same apartment or unit	$D_{nT,w}$	$\alpha_8 = 1$

3. Social Survey

In order to obtain values such as these weighting coefficients that are intended to represent which descriptors have more ou less influence in the acoustic comfort provided by the dwelling, it was developed a social survey based on a questionnaire [4].

The structure of the questionnaire was elaborated with short questions in a way it's easily understood so people could answer it quickly. These characteristics enabled the gathering of a significant number of responses (784 responses) using a fill tool online. In this way it was possible to obtain a good demographic representativity (figure 4) and estimate medium values that could be compared to the ones established on the evaluation scheme. The target public in this study were residents in Portugal with age between 26 and 65 years old.

The survey was applied also in a especific urbanization (figure 5), with 33 responses obtained, in order to confirm the data gathered using the fill tool online. As for the questions that integrated the survey, it was adopted the follow structure:

1. Initial questions to characterize the population sample
2. Intermediate questions to familiarize to the dealt matter
3. Final questions to indicate the values of discomfort

The first questions are basically to verify the population sample regarding the age, the local of residence, the number of occupants in the dwelling and some features about the dwelling itself. The second type of questions is a way for respondents to familiarize with the dealt matter and basically consists in questions to identify, from a list, the most uncomfortable noises. In this way, the respondents are already comparing the discomfort associated to the noises from the list. The sounds or activities listed are directly related to the list of descriptors considered in the acoustics evaluation scheme. Finally, the third type of questions are meant for the respondents to indicate a value, in a scale from zero to ten, that they feel it best represents the discomfort associated to the noise from the list as it's shown in Table II.

Table II. Scheme of final questions about the discomfort associated to each sound/activity

List of sounds or activities related to each descriptor	Numeric scale to represent the magnitude of discomfort towards each sound											
	0	1	2	3	4	5	6	7	8	9	10	N
Descriptor 1												
Descriptor 2												
Descriptor 3												
Descriptor 4												
Descriptor 5												
Descriptor 7												
Descriptor 8												

As shown in Table II, descriptor number six was not considered due to the specific type of sound/activity associated (impact sound exerted on floor of adjacent spaces used for commercial) and the difficulty to distinguish the discomfort related to these sounds and the ones in descriptor four (airborne sound radiate from adjacent spaces used for commercial). Therefore the medium values obtain for descriptor four are adopted for the descriptor six as well.

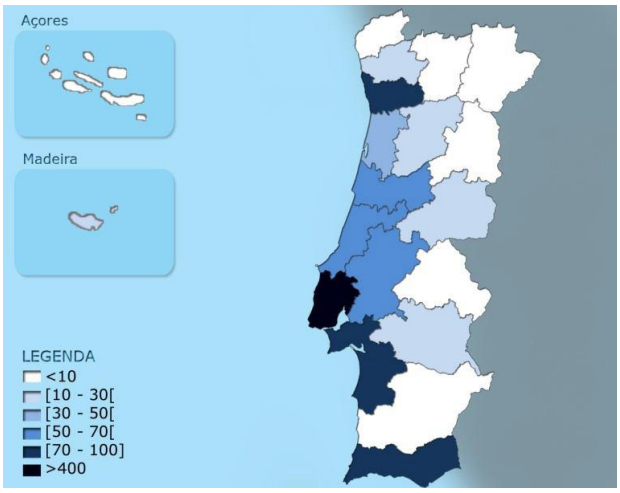

Figure 4.Demographic representativity of the responses gathered

Figure 5.A building of the urbanization where the survey was applied

4. Results

From data provided by the survey it was obtain the distributions of responses regarding each descriptor, as shown in figures six to twelve. Given the considerable dimension (over thirty responses) of the population sample it was possible to use the central limit theorem in order to do an approximation to the normal distribution, and thus, determine a medium value inserted in a 95% confidence interval (Table III).

The weighting coefficients established in the acoustic evaluation scheme has a base of forty points (the sum of all coefficients). In order to compare the values estimated to the ones in the acoustic evaluation scheme, each medium value estimated has his relative value in the sum of all weighting coefficients estimated.

Table III. Medium values of discomfort estimated

Weighting coefficient	Discomfort from noise		
	Medium value	Confidence interval 95%	%
α_1	4,09	[3,81-4,37]	10,9%
α_2	5,81	[5,50-6,12]	15,5%
α_3	3,60	[3,33-3,86]	9,6%
α_4	5,53	[4,45-6,62]	14,8%
α_5	6,36	[6,03-6,69]	17,0%
α_6	5,53	[4,45-6,62]	14,8%
α_7	3,26	[2,99-3,53]	8,7%
α_8	3,24	[3,02-3,45]	8,7%

Attending at the relative values estimated from the data of the survey applied with fill toll online and comparing them to the values estimated from the survey applied on a specific urbanization, as shown in figure 13, it's possible to verify that the values don't differentiate much. The largest differential between them is 3%.

Analyzing the values acquired it's easy to spot the descriptors associated to the type of sounds which the population sample considers the most discomforting. It's possible to identify descriptors two, four and five as the ones that disturb the most (descriptor six has the same value as four for reasons already mentioned). These descriptors are related to both airborne and impact sounds, from neighbors and from adjacent spaces used for commercial. As for the others descriptors, less discomforting, they are associated to noise from equipments, between living rooms and bedrooms in the same unit, and from common accesses. In the middle of these two groups is the descriptor one, associated to airborne sounds coming from the exterior.

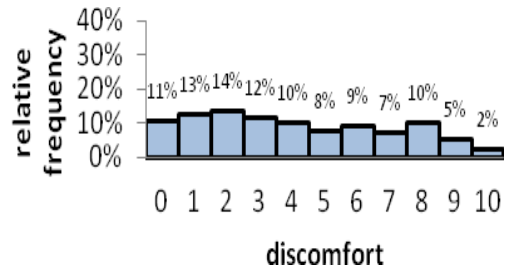

Figure 6. Discomfort related to descriptor 1 (α_1)

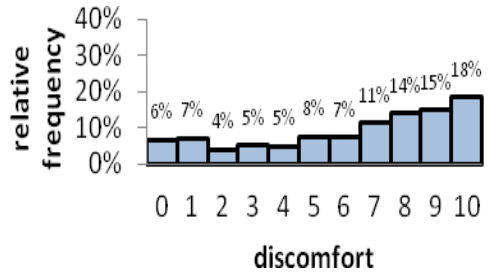

Figure 7. Discomfort related to descriptor 5 (α_5)

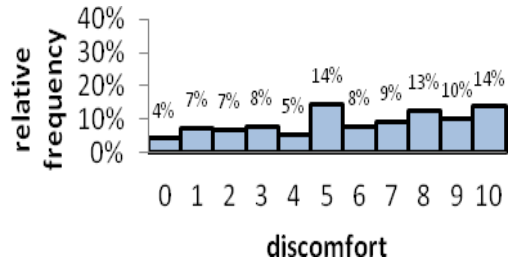

Figure 8. Discomfort related to descriptor 2 (α_2)

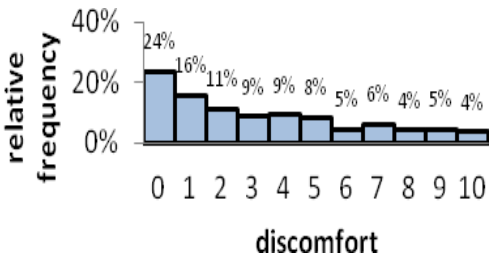

Figure 9. Discomfort related to descriptor 7 (α_7)

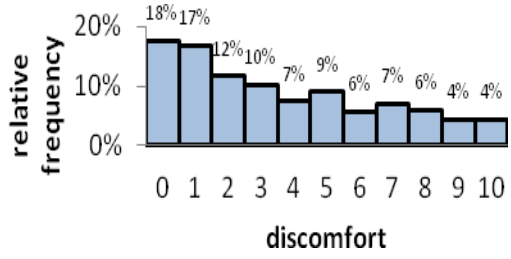

Figure 10. Discomfort related to descriptor 3 (α_3)

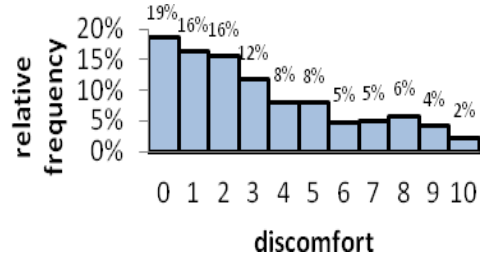

Figure 11.Discomfort related to descriptor 8 (α_8)

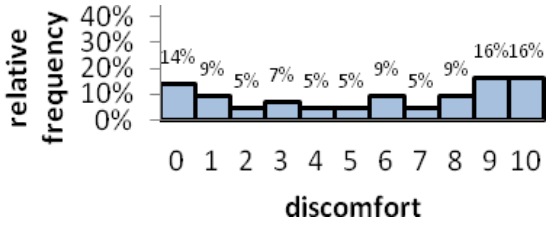

Figure 12. Discomfort related to descriptor 4 (α_4)

Putting these values in ascending order we get descriptors three, seven and eight forming the lower group, descriptor one on an intermediate level and descriptors two four and six in a higher group led by descriptor five. This order obtained is not very different from the one established in the acoustic evaluation scheme as shown in figure 14. The group of descriptors with higher weighting coefficients includes also numbers two, four, five and six. The group with lower weighting coefficients also includes descriptors number three and eight. The exception case, the descriptor number seven, associated to noise from equipments, which is given a much higher weigh in the evaluation scheme than the one estimated in the survey. As for descriptor number one, the weight given in the scheme coincides with the value estimated.

In general the medium values obtained with this study verify the ones in the acoustic evaluation scheme for dwellings. A few discrepancies are observed for descriptor three, related to noise from common spaces, which people in this survey gave a higher weight. The same situation is verified for descriptor eight, although this one is not even considered in Portuguese legislation, the results from the survey suggests that people find this descriptor to have more importance that is given by the evaluation scheme.

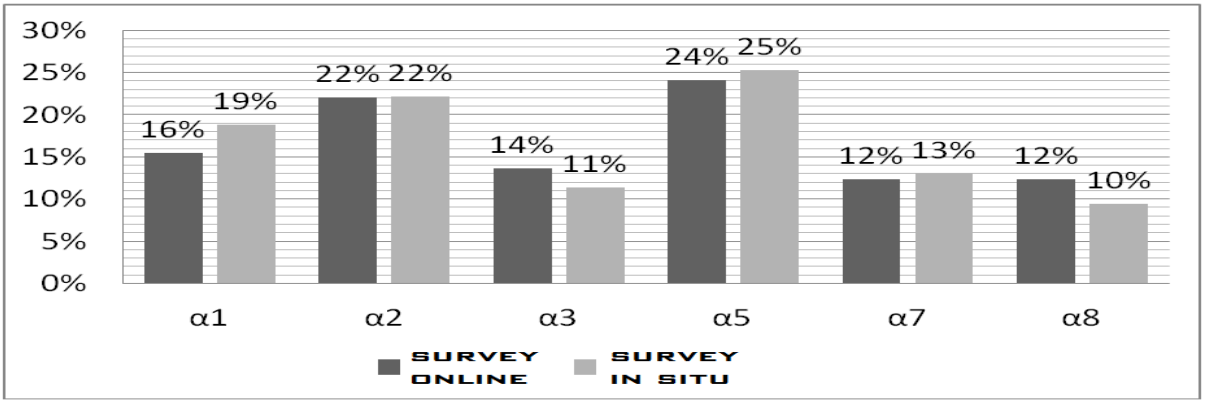

Figure 13.Values from survey applied online versus values from survey applied on a specific local

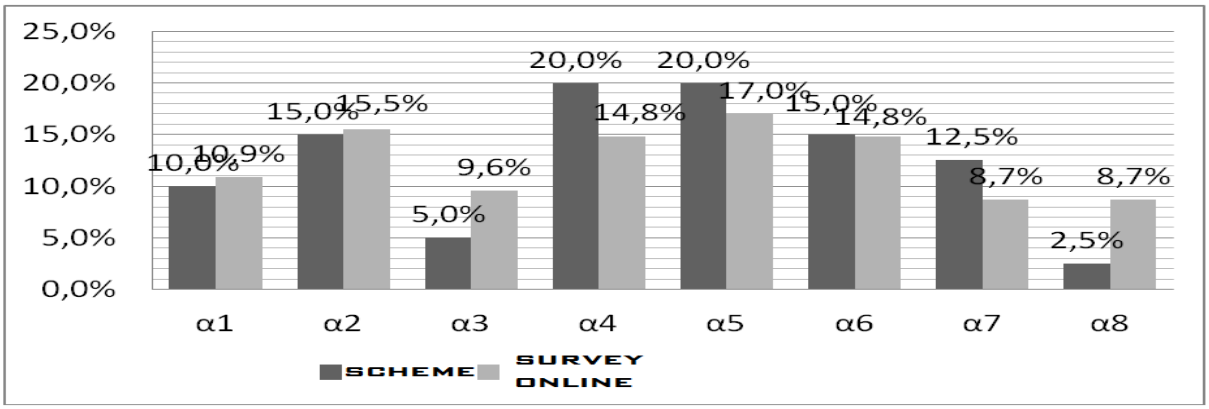

Figure 14.Values from the evaluation scheme versus values from survey applied online

5. Sensitivity analysis of the weighting coefficients

For a better understanding of the impact that these coefficients have on the dwelling's classification, it is considered a scenario in which all descriptors are displayed on the status of regulatory compliance, i.e., assigned a score of 1.0 to all of them. Then, by varying only one of the parameters in pair "weighting" / "score" is obtained the relation defined by equation 2. This relation is represented in Figure 15, where, based on values in the x and y axes, results the dwelling's final classification.

$$z = x \times y + (1 - x) \quad (2)$$

z – Dwelling's classification
y – Score given to coefficient x
x – Value of the weighting coefficient x (%)

From this analysis, one easily gets the score intervals, for a given value of weighting, which allow a variation in the final classification. To better understand, an example is given in Table IV, where for a weighting of 15%, are obtained the respective score intervals that have an effect on the final classification. This example is perfect to realize that descriptor two for instance, which has a weight of 15% in the evaluation scheme, requires a minimum score of 1.4 to have influence on final classification, in a situation of regulatory compliance for all the others descriptors.

Table IV. Score intervals for weighting of 15%

Δ z (variation in final classification)	y (score)
Δ z = 0	1,0 to 1,3
Δ z = 0,1	1,4 to 1,9
Δ z = 0,2	2,0 to 2,6
Δ z = 0,3	2,7 to 3,0

6. Conclusions

This study indicates that people identify certain types of sounds as being more uncomfortable and, therefore, there are acoustic insulations that play a more dominant role than others in the acoustic comfort provided by the dwelling.

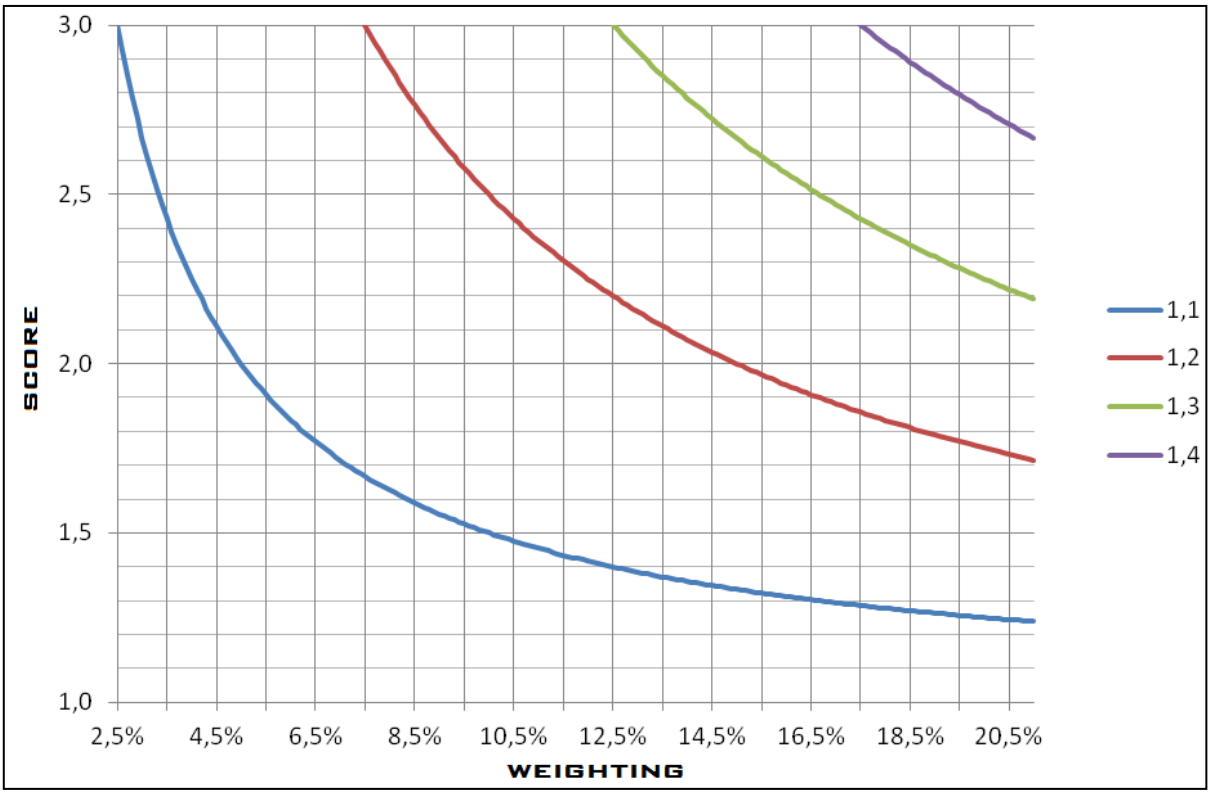

Figure 15. Dwelling's final classification according to weighting and score given to a descriptor

More specifically, are identified as having a higher weight in the acoustic quality of the dwelling, the airborne and impact sound insulation from neighbors and the airborne and impact sound insulation from adjacent spaces used for commercial. On the other hand, airborne sound insulation between common accesses and living room or bedrooms and airborne sound insulation between living rooms and bedrooms of the same apartment or unit are clearly the ones with less influence in the acoustic quality of the dwelling.

Although both the evaluation scheme as the investigation indicate the sound insulation between rooms and living rooms as less important than others, the importance attributed to this descriptor is greater in the investigation, suggesting that the value considered in the evaluation scheme is understated.

In general the medium values determined in this study validate the values defined in the acoustic classification's system for dwellings, thus validating a method that assigns different weights to various descriptors considered.

As for the influence that these coefficients have in the dwelling's classification, for a descriptor with high weight (15%), it takes a difference of about 0.3 points in the score given to that descriptor regarding the others, so that it alone has an impact of 0.1 on the final classification.

To summarize the importance of these coefficients for the evaluation scheme, they make the method more balanced, taking into account a subjective component, which reflects the preferences of the occupants.

References

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[3] J.V.Patrício;S.Antunes: A Methodology for Building Acoustics Assessment and Classification, in Portugal. INTER-NOISE 2011. Osaka Japan, September 4-7, 2011.

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