A methodology for building acoustics assessment and classification, in Portugal

Jorge Patrício, Sónia Antunes

[1] Laboratório Nacional de Engenharia Civil

Av. do Brasil, 101, 1700-066 Lisboa, Portugal

ABSTRACT

This paper presents a methodology to assess the overall acoustics quality of buildings, thus contributing for their classification in terms of acoustic comfort, and consequently in their acoustic sustainability.
The proposed methodology, which is expected to be implemented in the near future in Portugal, relies on two main evaluations: one related to buildings integration into the near environment (planning context); and other on the acoustic performance of their partitions, level of noise from service equipment, partitioning of rooms relatively to one another, and different usages available inside the buildings (i. e. apartments versus shops).
Three examples of this methodology implementation are presented in the paper, and some conclusions are extracted from the achieved results in close elation to the principles of buildings global sustainability.
Keywords: Acoustics, Sustainability, Evaluation

1. INTRODUCTION

In Portugal, the concept of sustainability in housing buildings is continuously growing, mainly due to energetic efficiency requirements set by buildings thermal legislation. In fact, the European Union through its issued recommendations and the support given to various research programs, has highly promoted the needs to rationalize energy use within its member countries, under the scope of a sustainable development.

However, the buildings sustainability should not be strictly confined to energy balances. It must also be related to other components of the individuals' well-being, in which the acoustics comfort inside buildings plays an important role. And, in this context, the acoustics is one of the most important one, as is inferred from the objectives of COST Action TU0901 [1].

There are several proposals [2, 3, 4] dealing with problems of classifying and certifying the global performance of buildings, using assessment procedures based on values of their acoustic insulation. However, few of them take into account the evaluation of the overall system, i. e. the building and its environmental integration.

In this paper it is proposed an integrated evaluation methodology for buildings in urban zones, which considers the performance of the buildings in terms of: *i*) the exterior noise environment *ii*) sound insulation; *iii*) noise from service equipment; *iv*) reverberation times; and *v*) distribution of pieces inside the building. This methodology relies on the assessment of three physical realities, using appropriate indicators:

i) one reality related to the vicinity;
ii) other with the building itself; and
iii) another with the lodging characteristics.

2. CRITERIA

In Portugal, under the scope of acoustic quality assessment of buildings and in buildings, the corresponding evaluation relies fundamentally in the compliance of the system (building) with the legal requirements, respectively the Noise Pollution Act (Decree-Law 09/2007) [5] and the Building Acoustics Code (Decree-Law 96/2008) [5].

The first legal document establishes the framework related to the exterior noise environment, and the second one establishes the acoustic comfort inside buildings, expressed by the sound insulation indicators (airborne sound and impact sound), the maximum noise level due to service equipment, and whenever necessary the reverberation time.

Nevertheless, the proposed evaluation is not only confined to physical indicators. The distribution of sensitive pieces within an apartment relatively to the exterior (façade facing traffic lines), the inter-relation between adjacent spaces inside building that could be potential noise sources (per. example Cafés or other shops), are also taken into account by this evaluation procedure, by a process of questioning.

It must be noted that despite being expressed conceptually, the respective global evaluation is inherently related to the autonomous building fraction (let's say the apartment).

So, within this framework, the corresponding assessment is based on the quantification of legal indicators (when applicable), and on the proposition of special conditions whenever the existing legislation does not cover certain aspects that could be considered relevant for the purpose.

In the process of indicators quantification (or weighting of questionings) for each physical reality, a value expressed in "points" is therefore attributed, which will be used to assess the level of that physical reality, and consequently the apartment global quality with a simple arithmetic procedure, as follows:

$$Level = \frac{1}{N}\sum_{i=1}^{N} Pt_i \qquad (1)$$

Where: N is the number of aspects under evaluation (physical realities); and Pt_i the number of points attributed to each aspect (indicators or questionings).

Finally, the global qualification index, for each domain of physical reality evaluation (environment, building, and lodging), will be framed as follows:

Level 0 – Low Quality: (**LQ**); Does not comply with the regulations and recommendations.

Level 1 – Basic Quality (**BQ**); It generally complies with the appropriate regulations and/or assures the minimum comfort conditions.

Level 2 – Recommended Quality (**RQ**); It implies an acoustic comfort higher than that set forth by national regulations.

Level 3 – High Quality (**HQ**); It allows a pattern of acoustic comfort with high exigency.

3. ASSESSMENT

3.1 Component: vicinity

3.1.1 Goals

The environmental integration of the building in terms of acoustics, must allow a suitable acoustic comfort to residents there living, thus contributing for a healthy life for the Humans.

3.1.2 Requirements

1. General:

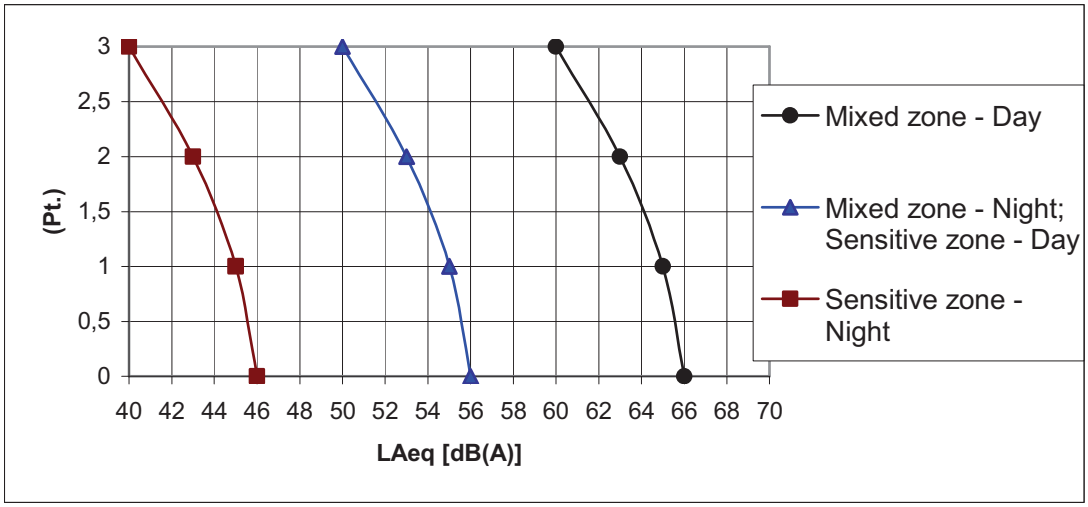
a) The area in which the building is located has a noise map? True = 2 Pts; False = 1 Pt

b) Aren't there potential noisy spots within the nearest vicinity (i. e. traffic lines, industrial parks, school gardens, discos, etc.)? True = 3 Pts; False = 1 Pt

c) Taking into account the land use planning in terms of acoustic zoning, the licensing procedure related to the building environmental integration was based just on

measurements or on a Municipal administrative classification of the area? True = 3 Pts; False = 1 Pt

2 - Environmental noise level (L_{den}; L_n) :



3.1.3 Vicinity evaluation criteria

The evaluation of the component vicinity will be calculated according the following equation:

$$Vicinity = \frac{1}{N}\sum_{i=1}^{N} Pt_i \qquad (2)$$

Where N is the number of the considered items for the assessment; in case maximum N = 4.

3.2 Component: building

3.2.1 Goals

The building conception must assure that the acoustic conditions of common access areas, such as halls, stairs, and landings, are suitable and provide acoustic comfort inside apartments, contributing for the building overall quality.

3.2.2 Requirements

General remarks regarding acoustic conditioning inside the common accessing spaces:

a) Into the main entrance (hall), were duly considered acoustic conditioning measures concerning exterior airborne noise? True = 2 Pts; False = 1 Pt

b) Into the areas of common accesses, were considered measures concerning the control of reverberation time? True = 3 Pts; False = 1 Pt

c) Into the areas of common accesses, were considered appropriate solutions concerning noise emitted by service equipments? True = 2 Pts; False = 1 Pt

d) Into the areas of common accesses, were considered specific measures concerning water installations (supply or waste)? True = 2 Pts; False = 1 Pt

e) For the areas of common access, were considered solutions concerning the airborne sound insulation to be provided by the transparent “roof”? True = 2 Pts; False = 1 Pt

3.2.3 Building evaluation criteria

The evaluation of the component building will be calculated according the following equation:

$$Building = \frac{1}{N}\sum_{i=1}^{N} V;F \tag{3}$$

Where N is the number of the considered items for the assessment; in case maximum N = 5.

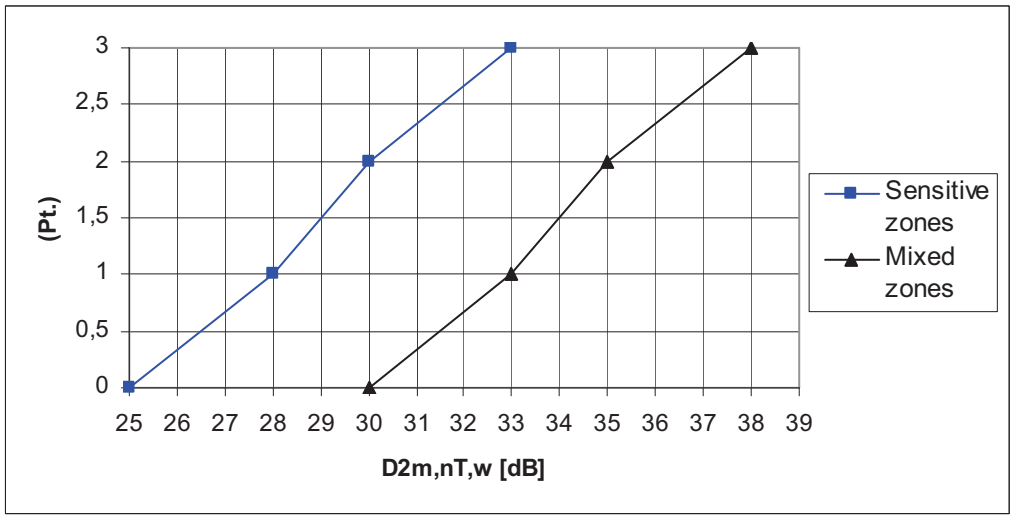
3.3 Component: dwelling

3.3.1 Goals

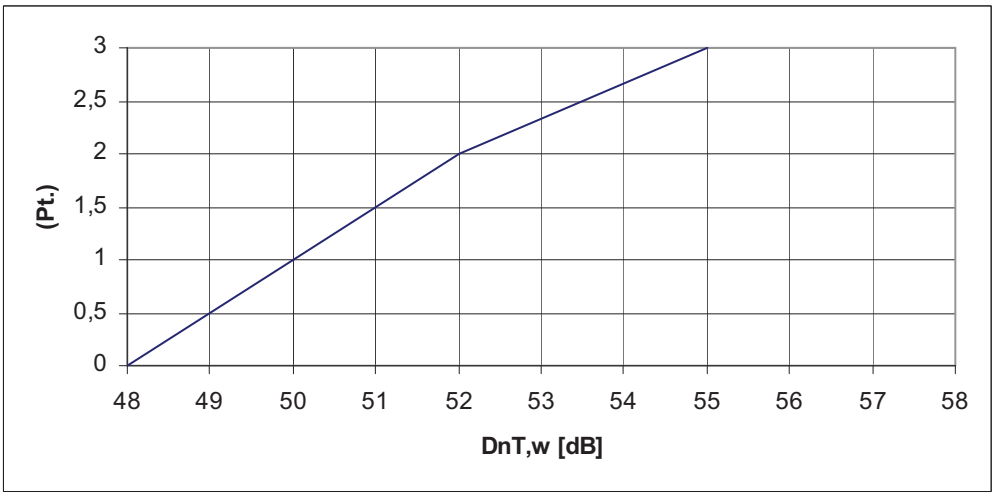
The dwelling should assure to the respective users an adequate acoustic comfort, in order to keep their quietness and tranquility relatively to external noise, and to other adjacent dwellings, as well as within specific spaces of the dwelling and their inter-relation with each other. In this sense, the used indicators are those set forth by the appropriate legal framework, including also the relative location of rooms in relation to each other and to potential interior partitioning.

3.3.2 Requirements

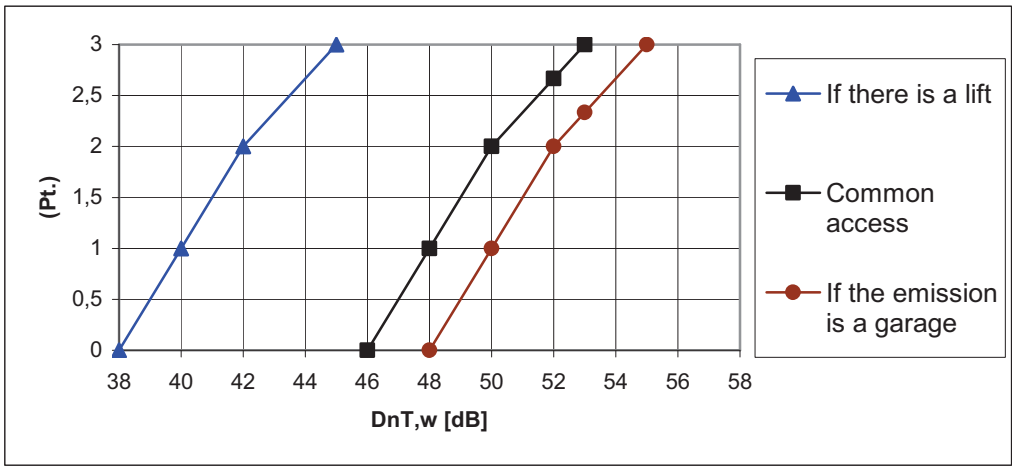
1. *Airborne sound insulation, $D_{2m,nT,w}$, (living rooms and bedrooms)*



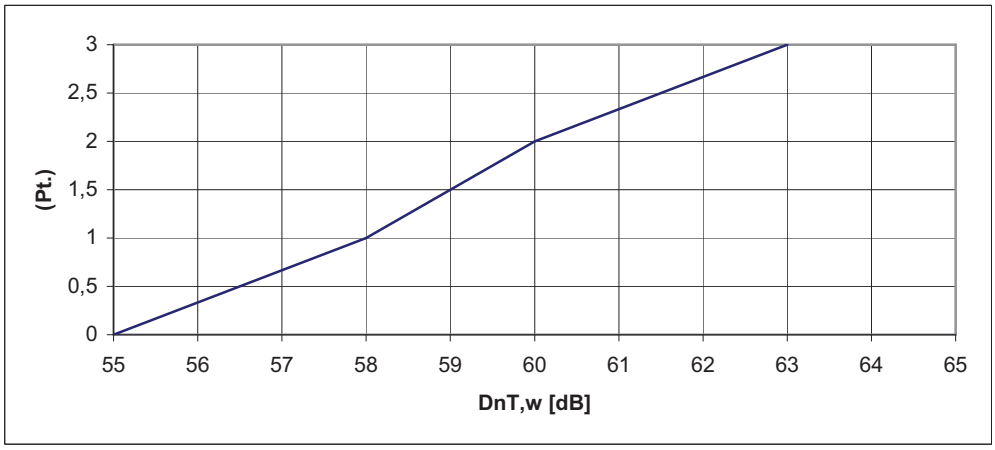
2. *Airborne sound insulation, $D_{n,w}$, (between rooms of emission apartment and living rooms and bedrooms of reception apartment)*



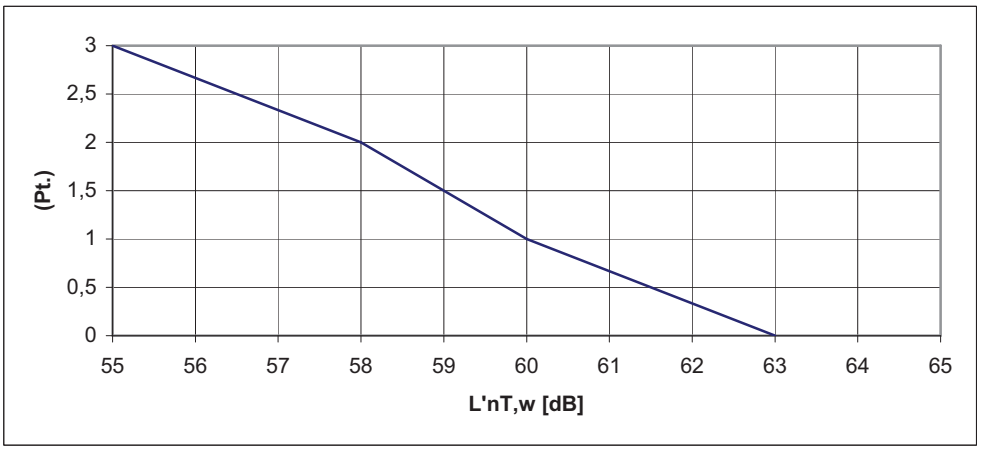
3. *Airborne sound insulation, $D_{n,w}$, between common accesses as emission places and living rooms and bedrooms of reception apartment*



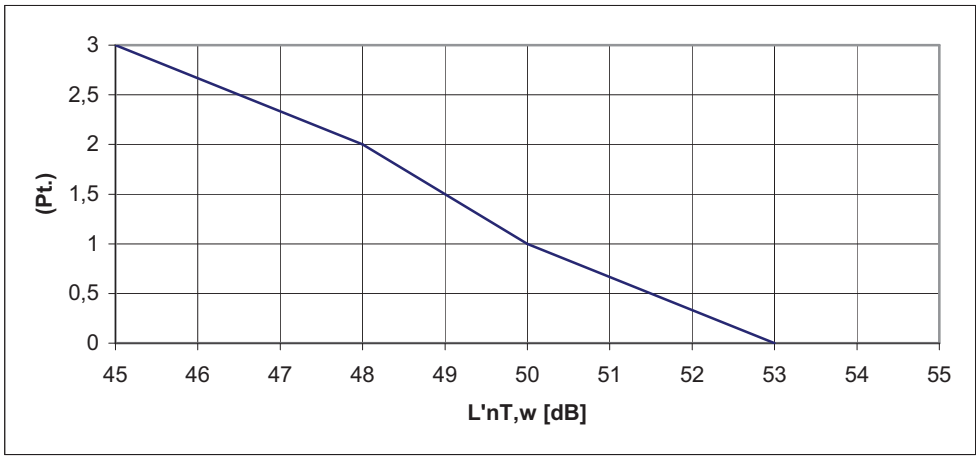
4. *Airborne sound insulation, $D_{nT,w}$, in bedrooms or living rooms (as reception spaces), due to impact sound exerted on floors of adjacent spaces used for commercial, industry, services or entertainment (as emission places)*



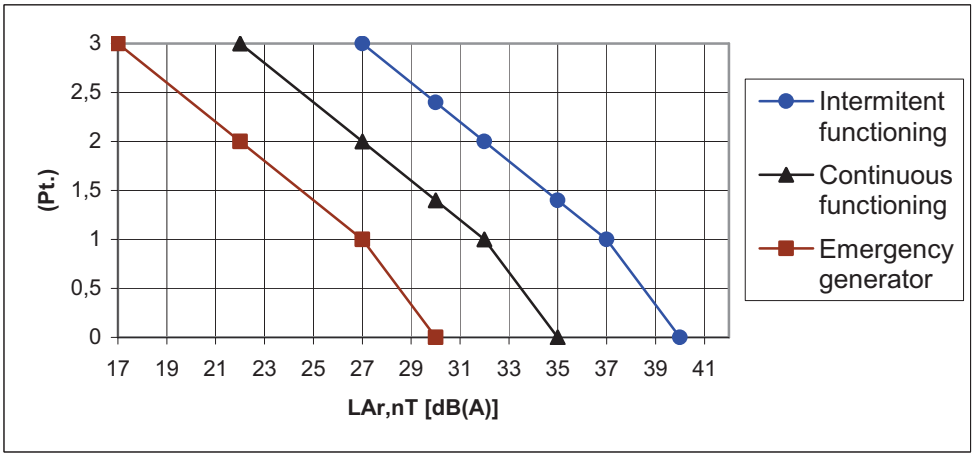
5. *Impact sound insulation, $L'_{nT,w}$, in bedrooms or living rooms (as reception spaces), due to impact sound exerted on other apartment floors or on common accesses (as emission places)*



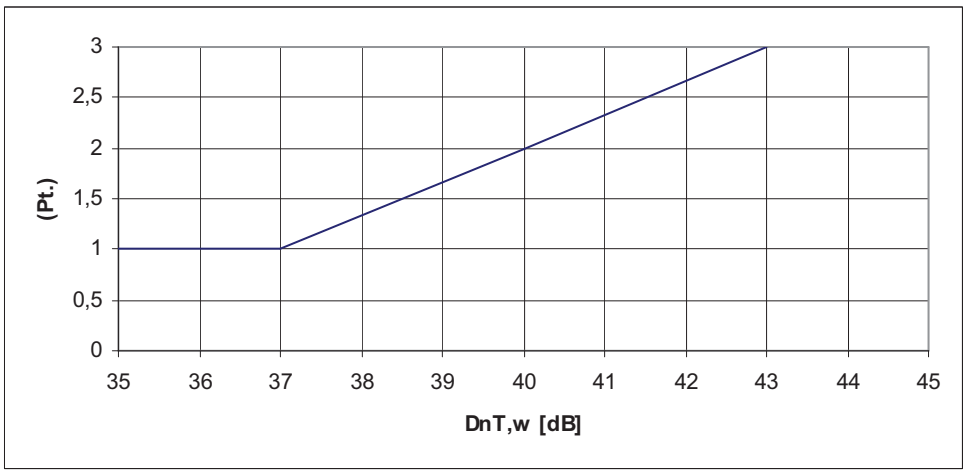
6. *Impact sound insulation, $L'_{nT,w}$, in bedrooms or living rooms (as reception spaces), due to impact sound exerted on floors of adjacent spaces used for commercial, industry, services or or entertainment (as emission places)*



7. *Noise level from equipment service, $L_{Ar,nT}$, such as lifts, water supply systems, garage doors, ventilation, rubbish, waste water, pumps, cooling etc., within bedrooms or living rooms*



8. *Airborne sound insulation, $D_{nT,w}$, between living rooms and bedrooms of the same apartment or unit*



9. General aspects of internal partitioning:

a) There is no vertical overlap between rooms with different types of use (p. ex. Living rooms above bedrooms)? True = 2 Pts; False = 0 Pt

b) There is no horizontal adjacency between rooms with different use p. (ex. kitchen versus bedrooms)? True = 2 Pts; False = 0 Pt

c) The bedrooms and the living rooms are not facing potential exterior noisy zones (p. ex. road traffic lines)? True = 3 Pts; False = 0 Pt

d) There are no commercial or entertainment spaces in the building? True = 2 Pts; False = 0 Pt

3.3.3 Dwelling evaluation criteria

The assessment of the component dwelling will be calculated according the following equation:

$$Dwelling = \frac{\sum_{1}^{N} \alpha_i Pt_i}{\sum_{i} \alpha_i} \tag{4}$$

Where N is the maximum number of items considered for the assessment, Pt_i the average points attributed to each item, and α_i the corresponding weighting coefficient as set in the Table 1.

Table 1 - Weighting coefficients for the component dwelling

Number of requirement	Coefficient α_i
1	5
2	3
3	2
4	5
5	4
6	5
7	4
8	1
9	2

4. EXAMPLES

In Table 2 three examples of implementation of this procedure are presented. The buildings selected for these assessments are recent (dated after 2009), located in the Lisbon surroundings, and were tested according to the requirements set forth by Portuguese Regulations in order to be put on the market. They correspond to housing buildings (two multi-familiar units: Seixal 1 and Estoril) and one uni-familiar unit: Seixal 2). The Seixal 1 and Seixal 2 are for medium economic classes and the Estoril for the very high economic classes.

The data presented for each building include the type of response to questionings (True or False), the sound insulation obtained with measurements, the evaluation for each component, and the global obtained result.

It must be stressed that whenever there are two values for the same item (sometimes this happens for sound insulation), the adopted value for the classification is not the averaged one, but the minimum of those measured. In this context, the evaluation will be on the safe side, mainly for users and buyers.

Also, for performance items: i) whenever the item does not exist in the building or in the

environment, the will be no value to be attributed; ii) whenever the item exists but was not measured due to non explicit reasons the attributed value expressed in points is 1, which corresponds to the basic value, let's say meaning there is conformity with legal framework; iii) for each item, whenever the building performance exceeds more than 5 dB units, then the attributed value is always equal to 3 points; for each technological item, whenever the obtained value leads to a very low assessment, it is adopted 0 as the minimum number of points (there are no negative scores).

Table 2 – Examples of assessment

	Requirement	Seixal 1	Assessment	Seixal 2	Assessment	Estoril	Assessment
Vicinity	1 a)	F; 1	**2,25**	F; 1	**2,25**	T; 2	**1**
	1 b)	T; 3		T; 3		F; 1	
	1 c)	T; 3		T; 3		F; 1	
	2	2		2		0	
Building	a)	F; 1	**1,4**	-	**-**	F; 1	**1,6**
	b)	F; 1		-		F; 1	
	c)	T; 2		-		T; 2	
	d)	T; 2		-		T; 2	
	e)	F; 1		-		T; 2	
Dwelling	1	(35); 3	**2,4**	(34); 3	**2,8**	(38); 3	**2,6**
	2	(53); 2,3		(58); 3		(59); 3	
	3	(46); 3		-		1*	
	4	-		-		-	
	5	(45); 3		(53); 3		(33); 3	
	6	-		-		-	
	7	1*		-		(27); 3	
	8	1*		1*		(47) 3	
	9 a)	T; 2		T; 2		T; 2	
	9 b)	T; 2		T; 2		F; 0	
	9 c)	T; 3		T; 3		F; 0	
	9 d)	T; 2		T; 2		T; 2	
Global			**2,0**		**2,5**		**1,7**

* - this score means there were no measurements performed, but the assessment must be considered.

5. CONCLUSIONS

This methodology is to be proposed within the Portuguese context for sustainability assessment of acoustic comfort in buildings and of buildings, envisaging its integration in a future multi-criteria analysis of buildings performance.

Also the recent creation of a COST Action TU0901 entitled ""Integrating and Harmonizing Sound Insulation Aspects in Sustainable Urban Housing Constructions" will be a suitable

framework for the implementation and for the spread of this methodology.

As enhanced, the proposed methodology allows the promoters, authorities and end users, to classify the buildings respecting to noise in three different and complementary levels: the vicinity, the building as a whole and the apartment (flat) as a private property. The presented procedure is very simple and easy to use, giving suitable and comprehensible outputs, which are really understandable for the community. It can be applied to new or old buildings, or even to ones which could be under rehabilitation process, revitalizing the cities and giving them appropriate reasons to live in.

In the examples, it is interesting to see that the building constructed for high quality economic classes may be classified as HQ in terms of dwelling, but just as BQ concerning its environmental integration (vicinity), and almost RQ for the building itself; being in global terms the poorest one (1.7). The uni-familiar building is the best one with excellent ranking both in terms of vicinity and dwelling, as it is (more or less) the Seixal 1. The reason for this lies in the fact that the Estoril unit is very good in terms of interior partitions, but very poor in terms of its location. It was constructed in a very touristic area, and despite of having a magnificent view of the Atlantic Ocean and adjoined beaches has a major traffic line nearby.

The assessments done and presented in Table 2 are coherent with the global analysis the buildings are normally subjected to by potential buyers.

The methodology is actually under development namely in terms of weighting factors and inclusion of possible additional indicators.

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