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Elements for an acoustic classification of dwellings and apartment buildings in France

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The aim of the study is to present elements for an acoustic classification of dwellings and apartment buildings. The goal would be to have similarly to energy performance of building or dwellings a classification of the acoustic performance from A (very good) to F (very bad) for example that would be easily understandable by a common person. The work carried out in the European COST Action TU0901 “Integrating and Harmonizing Sound Insulation Aspects in Sustainable Urban Housing Constructions” is concerned with the harmonization of acoustic descriptors used in Europe as the sound insulation classes. Sound insulation classes exist in more than 10 European countries for impact and airborne sound insulation. The different European approaches used to determine the acoustic performance classes are briefly described. A classification that could be implemented in France is proposed for discussion.

1 Introduction

The aim of the study is to present elements for an acoustic classification of dwellings and apartment buildings. The goal would be to have similarly to energy performance of building or dwellings a classification of the acoustic performance from A (very good) to F (very bad) for example that would be easily understandable by a common person. When considering buying an apartment, the consumer has access to the mandatory thermal diagnostic giving information on the apartment energy performance; it would also be in the consumer interest to have simple information defining the apartment acoustic comfort.

The work carried out in the European COST Action TU0901 “Integrating and Harmonizing Sound Insulation Aspects in Sustainable Urban Housing Constructions” [1] is concerned with the harmonization of acoustic descriptors used in Europe as the sound insulation classes. Sound insulation classes exist in more than 10 European countries for impact and airborne sound insulation. The different European approaches used to determine the acoustic performance classes are briefly described.

A classification that could be implemented in France based on the French acoustic regulation is proposed for discussion. It cannot at this stage be taken as a formal proposal; it should be taken as a working document. Acoustic classification is a complex subject since it does involved human sensibility and sensitivity to noise to define noise annoyance that can only be approached in a statistical way. Therefore, it has to be discussed with the different French acoustic experts as well as certification institutions, and state representatives in charge of the acoustic theme. Furthermore, it should be completed by a quite large psycho-socio-acoustic investigation in order to evaluate more precisely the correlation between in-situ measurements, the choice of acoustic indices, noise annoyance, the effect of background noise and noise emergence, etc....

2 Acoustic performance classes in different European countries

About ten (10) European countries have a system to classify the acoustic performance of apartment buildings. It should be noted that since the acoustic indicators defining the requirements in the European countries, in terms of airborne, impact and façade sound insulation as well as service noise, are different, the comparison between European acoustic classifications can be difficult [2-3]. Table 1 gives the classification in the different European countries when they exist.

It should be noted that in European countries with an acoustic classification, the number of classes varies between 3 and 5. Furthermore, the use of simplified expressions to standardize the acoustic indicator allows showing that a step of about 4-5 dB is chosen between the classes. The levels required by regulation correspond usually to the average class. Classes below average are used for existing buildings (constructed well before actual regulation) for which acoustic comfort is limited. To define the global class, all indicators have to fulfill requirement from that class.

Table 1: Existing classification in different European countries (from [3]).

Country	Class denotations (1)	CS Reference (latest version)	Link BC to CS	BC Ref. to CS	Comment	Classes for new dwellings	Classes for “old” dwellings
DK	A / B / C / D	DS 490 (2007)	+	Class C		A, B, C	D
FI	A / B / C / D	SFS 5907 (2004)	(–)	None	BC = Class C	A, B, C	D
IS	A / B / C / D	IST 45 (2011)	+ (3)	Class C (3)	(3)	A, B, C	D
NO	A / B / C / D	NS 8175 (2008)	+	Class C		A, B, C	D
SE	A / B / C / D	SS 25267 (2004)	+	Class C		A, B, C	D
LT	A / B / C / D / E	STR 2.01.07 (2003)	+	Class C		A, B, C	D, E
NL	I / II / III / IV / V	NEN 1070 (1999)	–	None	BC ~ Class III	I / II / III	IV, V
IT	I / II / III / IV	UNI 11367 (2010)	–	None	BC ~ Class III	I / II / III	IV
DE	III / II / I	VDI 4100 (2007) (5)	–	None	BC ~ Class I	III, II, I	None
FR	QLAC / QL (2)	Qualitel (2008)	–	None	(4)	QLAC / QL	None

Abbreviations: BC = Building Code (regulatory requirements); CS = Classification scheme
(1)Classes are indicated in descending order, i.e. the best class first.
(2)Class denotations are applied for sound insulation between dwellings, for facade only one performance level exists.
(3)A proposal for a new building code includes a reference to Class C, approval expected late 2011.
(4)German Society of Acoustics (DEGA) has published a recommendation for a labelling system with seven classes A-F and a colour code, the lower classes intended for old buildings. Ref.: DEGA-Empfehlung 103 (2009).

Each class generally corresponds to a defined acoustic perception situation, an annoyance, a sensibility or statistic comfort and to a global value expressed in dB for different type of noises. A class depends on the spectral content and intensity of the emitted noise and on the receptor sensitivity with respect to perception levels and intelligibility, on the receiving volume and its reverberation time (usually taken as 0.5 for living rooms). It is possible to obtain a relation liking acoustic performance and annoyance using models and/or in-situ sociologic and psychoacoustic investigations. Psychoacoustic studies have shown that about 15 to 20% of interrogated persons are affected or annoyed by noise with sound insulation levels defined by regulation, and that it is possible to describe a scale of perception and annoyance based on 2 classes of 5 dB each around the average class defined by regulation, for each type of noise. For these 5 classes, it is then expected that for the highest class less than 5% of the occupants would be annoyed by noise and for the lowest class more than 50%.

Furthermore, the annoyance due to noise is particularly important for sound source with an important low frequency spectral content, so performance index including the third octave band 50 to 80 Hz are planned to be used in the next future.

Finally, it should also be mentioned that when the classification is applied to a complete apartment building having several dwellings, then the global class for the building is given by the lowest obtained for the different dwellings.

2.1 Dutch approach

The Dutch approach is well described in [4]: the classification system is based on annoyance evaluation model using representative levels for different noise sources $L_{p,Aeq,source}$, sound insulation levels ($D_{nT,A}$ for example) and an acceptable noise level in the considered reception room L_{ref} (25 dB(A) for dwellings in residential area). A tolerance/acceptation value $C_{tolerance}$ and an information $C_{spectral}$ of sound source spectral content are also used depending on the noise source type. So, the level obtained in the reception volume for an airborne noise source located in a neighbor dwelling room is given by

$$L_r = L_{p,Aeq,source\ voisin} + C_{spectral} - D_{nT,A} - C_{tolerance} - L_{ref} \qquad (1)$$

By comparing these reception levels with sociologic and psychoacoustic investigations on noise annoyance, classes can be defined with respect to these levels. It is then possible to go back to a sound insulation level to define the classes.

Proceeding in a similar way with the different sound insulation levels (indoor, outdoor and service equipment), for an "average" disruptive source corresponding to a normal good use of a service equipment and standard noise generated by occupants [4], the two intermediary classes (Classes II and III) are defined as shown in Table 2. Class III corresponds to a basic acoustic comfort matching acoustic regulation requirements, class II is representative of a good comfort. The difference between Class II and III correspond to an evolution of 5 dB for the different indices allowing respecting the same balance of the different noise sources. Class III is associated to a percentage between 10 and 25% of possibly annoyed occupants; for Class II, the percentage goes down to values between 5 and 10%.

Table 2: Classes II and III definition in Holland (from [4]).

		Normal noise source	
	Index	Class III	Class II
Airborne sound insulation	$D_{nT,A}$	≥ 52 dB	≥ 57 dB
Impact sound insulation	$L'_{nTw}+C$	≤ 53 dB	≤ 48 dB
Façade sound insulation	$D_{2mnT}+C_{tr}$	≥ 23 dB	≥ 28 dB
Service equipment	L_{nAT}	≤ 30-35 dB	≤ 25-30 dB

2.2 German DEGA proposal

In 2009, the German acoustical society DEGA has proposed a 7 level classification [5]. Different sources of noise in dwellings (see Table 7) for the different classes are listed and associated to a class depending on their audibility and intelligibility aspects. The different classes are defined with their corresponding acoustic comfort level. Airborne and impact sound insulation, and service equipment noise are classified within 7 levels and corresponding requirement for the building components (R'_w, R_w, $L'_{n,w}$, $L_{AFmax,n}$) for each class is provided. A number of points is given depending on reached performance and the total number of points is used to obtain the global class of the building. Furthermore, this method grants extra points depending on investigation methods (performance measurements or prediction).

It is suspected that this point based approach could lead to an unbalance effect of the different type of noise sources.

2.3 Saint Gobain Isover approach

In 2007, Saint Gobain Isover proposed classes for acoustic comfort [6] based on a research project performed by Vienna University in Austria [7]. Based on calculations evaluating perception levels (audible or not) of different types of activities in a dwelling, as well as acoustic classes in different countries, conditions in terms of airborne and impact sound insulation were defined for four classes given in Table 3. Extra costs associated to modification of buildings to achieve the different acoustic classes were evaluated and found to be limited to 1 to 7% of the construction cost. Furthermore, it is indicated in [6] that calculations for concrete based buildings in some Austrian provinces do not show any significant correlation between sound insulation and total cost of construction.

Table 3: Classes proposed by Saint Gobain Isover in 2007 (from [6]).

Class	"Music"	"Comfort"	"Enhanced" *)	"Standard"
Airborne sound insulation between flats $D_{nT,w}$ +C (dB)	≥ 68 ($C_{50-3150}$)	≥ 63	≥ 58	≥ 54
Airborne sound insulation between the rooms within a flat (without doors), also incl. one-family houses $D_{nT,w}$ +C (dB)	≥ 48	≥ 48	≥ 45	≥ 40 **)
Impact sound insulation between flats $L'_{nT,w} + C_{I,50-2500}$ ***) (dB)	≤ 40	≤ 40	≤ 45	≤ 50
Impact sound insulation within a flat, also incl. one-family houses $L'_{nT,w} + C_{I,50-2500}$ ***) (dB)	≤ 45	≤ 45	≤ 50	≤ 55
*) minimum requirements for terraced houses **) if requested ***) for a transitional period $L'_{nT,w} + C_I$, values decreased by 2 dB				

2.4 GIAc/ADEME approach

The GIAc (Groupement de l'Ingénierie Acoustique) represents the acoustic engineering consultants companies and has worked for some times with financial support from French agency ADEME on defining the acoustic performance of a building to obtain the HQE (High Environmental Quality) certification [8]. The method developed since 1989 is based on the acoustic situation analysis of the building: a certain activity in a room generates noise that could be problematic in another room depending on the activities taking place there. The goal is to best adjust the acoustic performances to the different activities taking place in the building. A level of noise aggression and a tolerance level are defined for each room; correction terms are introduced depending on the type of noise sources and sensitivity level with respect to the reception room type. This method allows obtaining a balance between the different insulation levels as a function of the noise sources. The current method is believed to be based on calculations performed with global indices as well as at the 125 Hz octave band; the noise emergence is also taken into account (continuous, impulsive or unpredictable noise).

At the end, this GIAc/ADEME method will be quite precise and completely adaptable to very different types of situations and activities in a building, while taking into account an objective in terms of background noise adapted to each condition, as well as noise emergence. It is then a general method for any type of buildings that will allow differentiating any types of rooms as long as the different activities that can take place in the different rooms are defined.

The GIAc working group is expected to propose as well a classification by the end of 2012 based on the developed method.

It is believed that the Dutch approach even if it is less detailed and precise, is still close to the GIAc/ADEME method. However, the Dutch approach goes one step further by making the connection with insulation levels (airborne and impact sound) and service equipment noise to define an acoustic classification.

3 Elements for building acoustic classification in France

Based on this review on the different approaches for acoustic classifications found in Europe, an acoustic classification for apartment buildings based on the French acoustic regulation requirements is proposed. As mentioned previously, this proposal is obviously at this stage a working document that remains to be largely shared and discussed.

The goal is to define classes, each being expressed in terms of acoustic comfort understandable to general public.

3.1 Methodology

The acoustic performance classes would be noted from A (best performing) to F (least performing) to keep the similarity with the energy performance classes. An increment of 5 dB would be used for the insulation levels between classes, except for the insulation levels within a dwelling. Class C would be representative of the proposed modification of French acoustic regulation in 2009, based on the present regulation except with respect to the impact sound insulation and acoustic treatment of communal areas. Indeed, when establishing the 1999 regulation, it was suggested to change the requirement concerning impact sound from 58 dB to 55 dB within a few years; this modification has not yet been implemented. In 2010 [9], a comparison of the acoustic performance for a multistory apartment building satisfying the French acoustic regulation was performed with respect to different European countries requirements. In terms of airborne sound insulation, the results indicated that the building fulfilling the French acoustic regulation was mostly fulfilling the other considered national regulations. However, in terms of impact sound insulation, it appeared that the chosen building did not meet the requirements of a quite important number of countries in central and northern Europe. Technical solutions do exist to meet the modification of regulatory impact level L'_{nTw} from 58 to 55 dB since it would correspond to QUALITEL first level certification. An economic investigation was also carried and demonstrated that the extra cost due to such a modification was quite limited [9].

The basic assumption of the classifications is to consider that the modified acoustic regulation (modification regarding impact sound insulation and acoustic treatment of communal areas) allows to have a quite good balance between the different indoor and outdoor noise sources. Furthermore, it should be noted that the Dutch Class III corresponding to a basic acoustic comfort (define by Dutch regulation) and respecting a certain balance with the different noise sources, is relatively close to Class C proposed in this work. An increment of 5 dB will be used for the different indicators between two adjacent acoustic classes to keep the noise source balance. Moreover, it should be noted that the French acoustic regulation allows a 3 dB tolerance margin on the measured sound insulation levels (associated to measurement uncertainty); for the classification, a "no tolerance margin" could be proposed.

The current regulation does not take into account low frequencies, i.e. third octave bands from 50 to 80 Hz; thus the present classes proposition does not considered them either, which is not quite satisfying since it is common knowledge that this frequency range is important with respect to comfort. Nevertheless, discussions are taking place at the European level to integrate low frequencies in acoustic indices; research work should be performed on this subject with a strong link to acoustic comfort.

The proposed Class A and Class B include sound insulation between living and sleeping rooms within the same dwelling in addition to sound insulation with respect to the other dwellings and outdoor. Table 4 proposes the classes description with respect to acoustic comfort for a dwelling or residential unit; this description could be improved still further.

Table 4: Proposed classes and occupants comfort for a residential unit.

Class A Excellent acoustic comfort
Class B Good acoustic comfort
Class C Average acoustic comfort (acoustic insulation reinforced with respect to 1999 French regulation requirements). Noise from other dwellings or from outside can be perceived.
Class D Limited acoustic comfort Annoyance due to sound transmission from other dwellings or from outside is quite possible. Confidentiality is not totally insured.
Class E Poor acoustic comfort Annoyance due to sound transmission from other dwellings or from outside should be anticipated. Confidentiality should not be expected.
Class F Acoustically unsanitary conditions.

For a multi-apartment building, the class is first evaluated for each dwelling; the class for the total building is then obtained from the dwellings lowest class and the communal areas class. In this way, it could be expected to avoid having very different classes for dwelling (such as costly and luxurious apartments with high acoustic comfort and cheap and small apartments with bad acoustic comfort).

In a first step, on the basis of building and dwellings plan, an evaluation of the acoustic performance of the different apartments has to be realized by prediction using standardized methods. Acoustic measurements for performance validation would have to be achieved to validate building and dwellings classification. Obviously, acoustic measurements on the total number of dwellings will not be possible; thus the acoustic expert role would have to be reinforced for selecting dwellings and situation the least favorable with respect to acoustic performance. Most probably, a minimum percentage for each dwelling type which acoustic performance would have to be verified by measurements would have to be defined.

The stages to define the acoustic comfort class associated to a multi apartment building would then be

- For each apartment, define the acoustic comfort class for each category "Airborne sound insulation", "Impact sound insulation", "Service equipment noise", "façade sound insulation". The acoustic comfort class is given by the lowest class obtained for these different categories.
- For the building, the comfort class is given by the lowest class obtained for the different apartments, and from the "acoustic treatment of communal areas" category.

If several classes can be determined for a category, then the lowest class obtained is always retained.

The different acoustic comfort classes associated with the different categories are not all listed below; only some examples on how the classes could be defined are given in the next sections. The limits given for each category are for reception rooms with a reverberation time of 0.5 s over the entire frequency range.

3.2 Comfort classes for indoor airborne sound insulation

Different class levels are to be defined for each configuration taken into account in the French acoustic regulation regarding airborne sound insulation; airborne sound sources being inside the building. Table 5 gives the different proposed class levels in terms of airborne sound insulation global index $D_{nT,A}$ between a room in a dwelling (emission room) and a room in a different dwelling (reception room).

Table 6 gives the different proposed class levels in terms of airborne sound insulation global index $D_{nT,A}$ between living and sleeping rooms in the same dwelling. This requirement does not exist in French acoustic regulation; the Dutch classifications definition was used as a base. It should be mentioned that Class A defined for airborne sound insulation within the same dwelling between a living room and a sleeping room ($D_{nT,A} \geq 53$ dB) corresponds to the airborne sound insulation required between a room in a dwelling and a living or sleeping room located in another dwelling (i.e. Class C in Table 5).

Table 5: Proposed classes for airborne sound insulation between rooms of different dwellings – $D_{nT,A}$ in dB.

Emission room : room in dwelling	Reception room: room in different dwelling	
	Living and sleeping room	Kitchen and bathroom
Class A	≥ 63	≥ 60
Class B	≥ 58	≥ 55
Class C	≥ 53	≥ 50
Class D	≥ 48	≥ 45
Class E	≥ 43	≥ 40
Class F	<43	<40

On the same basis and to follow the different requirement in the French acoustic regulation, different class levels in terms of airborne sound insulation global index $D_{nT,A}$ have been elaborated regarding airborne sound insulation between a indoor hallway and a room in a dwelling (reception room), between an individual or collective garage and a room in a dwelling (reception room), and between a commercial space and a room in a dwelling (reception room).

Table 6: Proposed classes for airborne sound insulation between rooms in the same dwelling – $D_{nT,A}$ in dB.

Reception room : Sleeping room	Emission room:	
	Living room	Kitchen and bathroom
Class A	≥ 53	≥ 45
Class B	≥ 43	≥ 35
Class C	≥ 33	≥ 25
Class D	≥ 27	≥ 20
Class E	≥ 22	≥ 20
Class F	<22	<20

3.3 Comfort classes for indoor impact sound insulation

Table 7 gives the different proposed class levels in terms of impact sound insulation global index $L'_{nT,w}$ in a living or sleeping room as reception room as function of different emission room type situated in a different dwelling. Table 8 gives the different proposed class levels in terms of impact sound insulation global index $L'_{nT,w}$ between rooms in the same dwelling. This requirement does not exist in French acoustic regulation; the Dutch classifications definition was used as a base. As previously mentioned, Class A defined for impact sound insulation within the same dwelling between a living room and a sleeping room ($L'_{nT,w} \leq 55$ dB) corresponds to the impact sound insulation required between a room in a dwelling and a living or sleeping room located in another dwelling (i.e. Class C in Table 7).

Table 7: Proposed classes for impact sound insulation between dwelling living and sleeping rooms and a room not in the same dwelling – $L'_{nT,w}$ in dB.

Reception room : Living or sleeping room	Emission room:	
	Hallways and garages[1]	Other rooms[2]
Class A	≤ 48	≤ 45
Class B	≤ 53	≤ 50
Class C	≤ 58	≤ 55
Class D	≤ 63	≤ 60
Class E	≤ 68	≤ 65
Class F	> 68	> 65

[1] excepted (i) balconies and loggias not directly located above reception room, (ii) stairs above 3rd floor if elevator in building, (iii) technical rooms, (iv) cellars and collective garages located at the same level or below the dwellings living or sleeping rooms.

[2] Any other rooms not located in the dwelling, different from hallways, garages and the exceptions listed above.

Table 8: Proposed classes for impact sound insulation between rooms in the same dwelling – $L'_{nT,w}$ in dB.

Reception room : Sleeping room	Emission room: living room, kitchen and bathroom
Class A	≤ 55
Class B	≤ 65
Class C	≤ 75
Class D	≤ 85
Class E	≤ 95
Class F	> 95

3.4 Comfort classes for service equipment noise

Table 9 gives the different proposed class levels in terms of standardized acoustic pressure level L_{nAT} for service equipment noise emitted under normal functioning of a dwelling individual heating or air-conditioning appliance.

On the same basis and to follow the different requirement in the French acoustic regulation, different class levels in terms of service equipment noise global index L_{nAT} have been elaborated regarding mechanical ventilation system under minimal air-flow conditions and building collective service equipment. It should be noted that the minimum level for service equipment noise global index L_{nAT} has been set to 25 dB which is expected to be a realistic level for background noise.

Table 9: Proposed classes for an individual service equipment noise perceived in dwelling – Individual heating or air-conditioning system – L_{nAT} in dB.

Individual service equipment	Reception room in same dwelling		
	Living and sleeping rooms	Closed Kitchen	Open Kitchen
Class A	≤ 25	≤ 40	≤ 30
Class B	≤ 30	≤ 45	≤ 35
Class C	≤ 35	≤ 50	≤ 40
Class D	≤ 40	≤ 55	≤ 45
Class E	≤ 45	≤ 60	≤ 50
Class F	> 45	> 60	> 50

3.5 Comfort classes for façade sound insulation

The airborne sound insulation with respect to outdoor noise $D_{nT,A,tr}$ for living and sleeping rooms as well as kitchen (as reception room) is given for the different proposed comfort classes in Table 10 ; the comfort classes are defined with respect to the requirement $D_{nT,A,tr\ -regulation}$ that depends on the location of the building with respect to ground transportation infrastructures (railways, roads with associated traffic) and airports. In a quiet zone, the minimum value required for $D_{nT,A,tr\ -regulation}$ is 30 dB ; it can go up to 47 dB for buildings very close to an airport.

Table 10: Proposed classes for an individual service equipment noise perceived in dwelling – Individual heating or air-conditioning system – L_{nAT} in dB.

	Reception room Living and sleeping rooms and Kitchen
Class A	$\geq D_{nT,A,tr\text{-}regulation}+10$
Class B	$\geq D_{nT,A,tr\text{-}regulation}+5$
Class C	$\geq D_{nT,A,tr\text{-}\ regulation}$
Class D	$\geq D_{nT,A,tr\text{-}\ regulation}-5$
Class E	$\geq D_{nT,A,tr\text{-}\ regulation}-10$
Class F	$< D_{nT,A,tr\text{-}\ regulation}-10$

3.6 Comfort classes for acoustic treatment of communal areas

Acoustic treatment of communal areas to limit reverberation time is also a requirement in French acoustic regulation. It is defined in terms of equivalent absorption area. A defined ratio between the equivalent absorption area and the floor surface area is indeed required. Then, this ratio would also have to be defined for the different proposed comfort classes. It is not discussed here due to paper length limitation.

4 Conclusion

In this work, a classification based on the French acoustic regulation has been proposed for discussion. It cannot at this stage be taken as a formal proposal but only as a working document. Acoustic classification is a complex subject ; more work is certainly necessary, especially a large psycho-socio-acoustic investigation in order to evaluate more precisely the correlation between in-situ measurements, the choice of acoustic indices, noise annoyance, the effect of background noise and noise emergence, etc.... Furthermore including the low frequencies aspect should be evaluated.

Acknowledgments

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