Sound classification of dwellings

Comparision of schemes in Europe and interaction with legislation [Invited keynote speaker]

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SOUND CLASSIFICATION OF DWELLINGS – OVERVIEW SCHEMES IN EUROPE AND INTERACTION WITH LEGISLATION

CLASSIFICAZIONE ACUSTICA DELLE ABITAZIONI - SINTESI DELLE PROCEDURE UTILIZZATE IN EUROPA ED INTERAZIONE CON I LIMITI DI LEGGE

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1. Introduction

In most countries in Europe, building regulations specify minimum requirements concerning acoustical conditions for new dwellings. The requirements relate to airborne and impact sound insulation, noise levels from traffic and technical installations as well as other acoustical and noise aspects.

However, complying with legal requirements does not guarantee satisfactory conditions for the occupants in dwellings, and several countries have introduced sound classification schemes with classes intended to reflect different levels of acoustical comfort. Consequently, acoustic requirements for a dwelling can be specified as the legal minimum requirements or - if available - as a specific class in a classification scheme. While legal sound insulation requirements for dwellings have existed for more than 50 years in several countries, schemes describing classes of acoustic quality of dwellings have been introduced during the past 1½ decade.

Acoustic classification schemes for dwellings exist in nine countries in Europe. The schemes specify class criteria concerning several acoustic aspects like the building regulations.

There are significant discrepancies between the European schemes, among these descriptors, number of quality classes, intervals between classes and levels of classes. The status of the classification schemes in relation to the legal requirements varies. In some countries there is no link between the building code and the classification standard. In other countries they are strongly "integrated" and the building code refers to a specific class in the classification standard rather than describing the requirements. By referring to a class, a building code draws attention to the facts that the legal requirements are minimum requirements and that possibilities of voluntary specification and design for better acoustic quality exist. If a classification scheme is not linked to building regulations, its impact will probably be less strong, unless there are other incentives.

This paper presents an overview of current sound classification schemes for dwellings in nine countries in Europe and describes the main criteria for sound insulation between dwellings.

2. Overview classification schemes in Europe and interaction with legislation

Sound classification schemes in Europe are national schemes, the majority being published by national standardization organizations. Only in Germany and France, the schemes are published by "private" organizations.

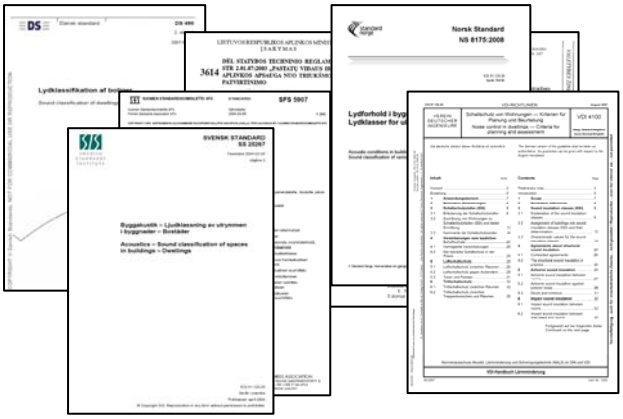

Figure 1 – Seven of nine sound classification schemes in Europe are published by national standardization organizations. Two schemes are published by "private" organizations.

An overview of existing sound classification schemes for dwellings is found in Table 1. For each scheme the relation to the building code is indicated in the table. The schemes specify class criteria concerning several acoustic aspects. The regulatory main requirements for airborne and impact sound insulation between dwellings are indicated in Section 4, and the main class criteria are described in Section 5. An overview of standardized sound insulation field descriptors is found in Section 2.

Table 1 – European schemes for sound classification of dwellings with information about relation to building codes.

European schemes for sound classification of dwellings February 2009

Country	Class denotations (1)	Interaction BC and CS	CS Reference (latest version)	
Denmark (DK)	A / B / C / D	BC refers to class C	DS 490 (2007)	[1]
Finland (FI)	A / B / C / D	BC refers to class C	SFS 5907 (2004)	[2]
Iceland (IS)	A / B / C / D	None (3)	IST 45 (2003)	[3]
Norway (NO)	A / B / C / D	BC refers to class C	NS 8175 (2008)	[4]
Sweden (SE)	A / B / C / D	BC refers to class C	SS 25267 (2004)	[5]
Lithuania (LT)	A / B / C / D / E	BC refers to class C	STR 2.01.07 (2003)	[6]
Netherlands (NL)	1 / 2 / 3 / 4 / 5	None, but BC ~ Class 3	NEN 1070 (1999)	[7]
Germany (DE)	III / II / I	None, but BC "equals" Class I	VDI 4100 (2007)	[8]
France (FR)	QLAC / QL (2)	None (4)	Qualitel (2008)	[9]

Abbreviations: BC = Building Code (regulatory requirements); CS = Classification scheme

Notes:

(1) Classed are indicated in descending order, i.e. the best class first.

(2) The indicated class denotations are applied for sound insulation between dwellings, but there is only one performance level for e.g. facade sound insulation.

(3) For sound insulation between dwellings, BC recommends limit values as for Class C, although the regulatory requirements in the BC are weaker than Class C.

(4) Class/label QL for airborne sound insulation between dwellings equals BC requirement. For impact sound level, QL is 3 dB stricter than the BC.

The different classes in the classification schemes are intended to reflect different levels of acoustical comfort. Thus, to be able to make a qualified choice of sound class, it is of course relevant to know the degree of acoustical comfort or occupants' satisfaction for the respective classes.

Example: Concerning regulatory sound insulation requirements for dwellings, the Danish Building Regulations 2008 refer to Class C in DS 490:2007. This standard also defines limits for dwellings with better acoustic conditions (Classes B and A) than specified in the regulatory minimum requirements (Class C). Furthermore, the standard also includes a weaker Class D intended for renovated dwellings, where improvement up to Class C is inappropriate (e.g. for architectural reasons), impossible (for technical reasons) or too expensive. In DS 490 are found brief definitions of classes, and an Annex describes in more detail the principles for occupants' subjective evaluation and provides information about expected percentage of satisfied and dissatisfied people for the respective classes. Summarized information based on DS 490 is found in Table 2.

Table 2 – Occupants' expected satisfaction for different sound classes according to DS 490:2007. Summary based on information in DS 490.

Sound classes describing acoustic conditions in dwellings		**Occupants' evaluation**	
Class	**Characteristics according to DS 490**	Good or very good	Poor
A	Excellent acoustic conditions Occupants will be disturbed only occasionally by sound or noise	> 90%	
B	Significant improvement compared to minimum given in class C Occupants may be disturbed sometimes	70 to 85%	< 10%
C	Sound class intended as the minimum for new buildings	50 to 65%	< 20%
D	Sound class intended for older buildings with less satisfactory acoustic conditions, e.g. for renovated dwellings. Not intended for new buildings.	30 to 45%	25 to 40%
Note: Within each sound class the percentage satisfied or dissatisfied occupants may differ somewhat from one acoustic criterion to another. The grouping is mainly based on the subjective assessments of airborne sound between dwellings and impact sound from adjacent dwellings. For details, see DS 490.			

3. Sound insulation field descriptors

Sound insulation requirements are expressed by descriptors defined in standards. Within building acoustics, ISO standards are implemented as European (EN) standards and national standards The current international descriptors for evaluation of airborne and impact sound insulation are defined in ISO 717:1996 [10]. Table 3 provides an overview of the basic 1/3 octave ISO 717 field descriptors (single-number quantities) and the spectrum adaptation terms intended for specification and test of:

- Airborne sound insulation between dwellings
- Airborne sound insulation for facades
- Impact sound insulation between dwellings

The single-number quantities and the spectrum adaptation terms are derived from values measured according to ISO 140 [11]. The spectrum adaptation terms have been introduced to take into account different spectra of noise sources, cf. Table 4. In Table 3, the total number of descriptors is indicated. The issue of descriptors is further elaborated in [12].

Table 3 – ISO 717 descriptors for evaluation of sound insulation in buildings

ISO 717:1996 descriptors for evaluation of field sound insulation	Airborne sound insulation between rooms (ISO 717-1)	Airborne sound insulation of facades (1) (ISO 717-1)	Impact sound insulation between rooms (ISO 717-2)
Basic descriptors (single-number quantities)	R'_w $D_{n,w}$ $D_{nT,w}$	R'_w $D_{n,w}$ $D_{nT,w}$	$L'_{n,w}$ $L'_{nT,w}$
Spectrum adaptation terms (listed according to intended main applications)	*None* C $C_{50\text{-}3150}$ $C_{100\text{-}5000}$ $C_{50\text{-}5000}$	*None* C C_{tr} $C_{50\text{-}3150}$ $C_{tr,50\text{-}3150}$ $C_{100\text{-}5000}$ $C_{tr,100\text{-}5000}$ $C_{50\text{-}5000}$ $C_{tr,50\text{-}5000}$	*None* C_I $C_{I,50\text{-}2500}$
Total number of descriptors	3 x 5 = 15	3 x 9 = 27	2 x 3 = 6
Note 1: For facades, the complete indices for R'_w, $D_{n,w}$, $D_{nT,w}$ are found in ISO 717.			

Table 4 – Relevant spectrum adaptation terms for different types of noise sources.

C Spectrum 1: A-weighted pink noise	**C_{tr}** Spectrum 2: A-weighted urban traffic noise
Living activities (talking, music, radio, tv)	Urban road traffic
Children playing	Railway traffic at low speeds
Railway traffic at medium and high speed	Aircraft propeller driven
Highway road traffic > 80 km/h	Jet aircraft large distance
Jet aircraft short distance	Disco music
Factories emitting mainly medium and high frequency noise	Factories emitting mainly low and medium frequency noise
Ref.: Table A.1 from ISO 717-1:1996. The spectra 1 and 2 are defined in ISO 717-1.	

A requirement may be expressed as the sum of a single-number quantity and a spectrum adaptation term or solely as the single-number quantity. Examples of airborne and impact sound insulation requirements could be:

$D_{nT,w} \geq 55$ dB; $L'_{nT,w} \leq 50$ dB;

$D_{nT,w} + C \geq 55$ dB; $L'_{nT,w} + C_I \leq 50$ dB;

$D_{nT,w} + C_{50\text{-}3150} \geq 55$ dB $L'_{nT,w} + C_{I,50\text{-}2500} \leq 50$ dB

For some types of buildings, e.g. for light-weight buildings, it is important to include low-frequency spectrum adaptation terms or other criteria taking into account low frequencies, cf. e.g. [12] or [13].

4. Regulatory sound insulation requirements in Europe

4.1 Sound insulation between dwellings

The legal main requirements on airborne and impact sound insulation between dwellings in 24 European countries are presented in Figure 3 and 4. In order to facilitate a comparison between countries, all requirements have been converted into estimated equivalent values of R'w and L'n,w based on assumptions about rooms and construction types. In case of an equivalent value being an interval, the average value has been indicated. For further information and details, see comments on results from previous surveys in e.g. [14] and [15].

A comparison between the 24 different countries reveals significant discrepancies descriptors and requirements. For both airborne and impact sound insulation requirements, several descriptors are applied in Europe. Examples of descriptors applied:

- Airborne sound insulation, e.g.: R'_w; $R'_w + C$; $R'_w + C_{50\text{-}3150}$; $D_{nT,w}$; $D_{nT,w} + C$
- Impact sound pressure level, e.g.: $L'_{n,w}$, $L'_{n,w} + C_{I,50\text{-}2500}$; $L'_{nT,w}$; $L'_{nT,w} + C_I$
- Besides, there are variants; recommendations and special rules

The most recent version of the standard EN ISO 717 [10] has contributed to the diversity in descriptors by allowing many different descriptors and by introducing spectrum adaptation terms with different extended frequency ranges.

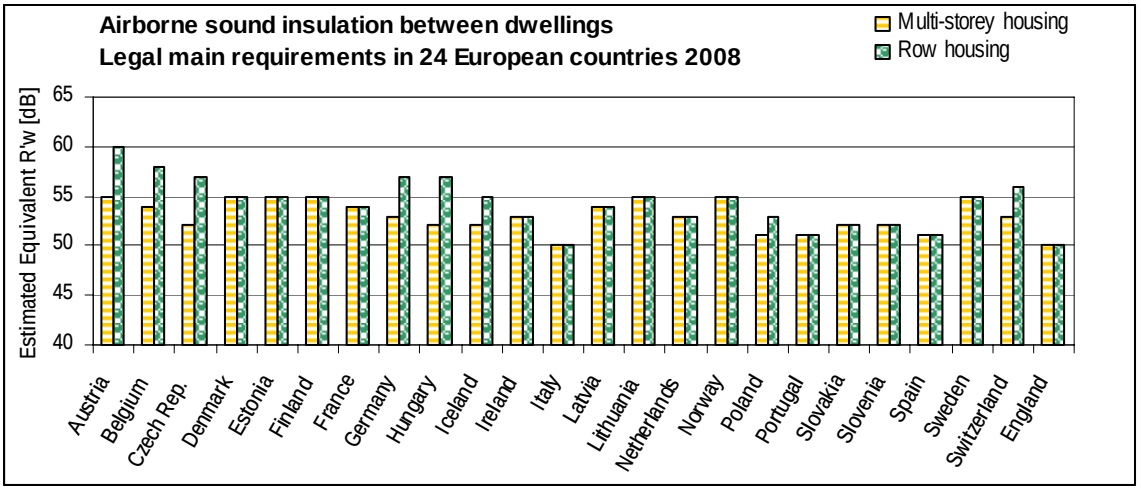

Figure3 – Overview of requirements for airborne sound insulation between dwellings (minimum values). Graphical presentation of estimated equivalent values of R'w.
Note: The equivalent values are estimates only, as exact conversion is not possible.

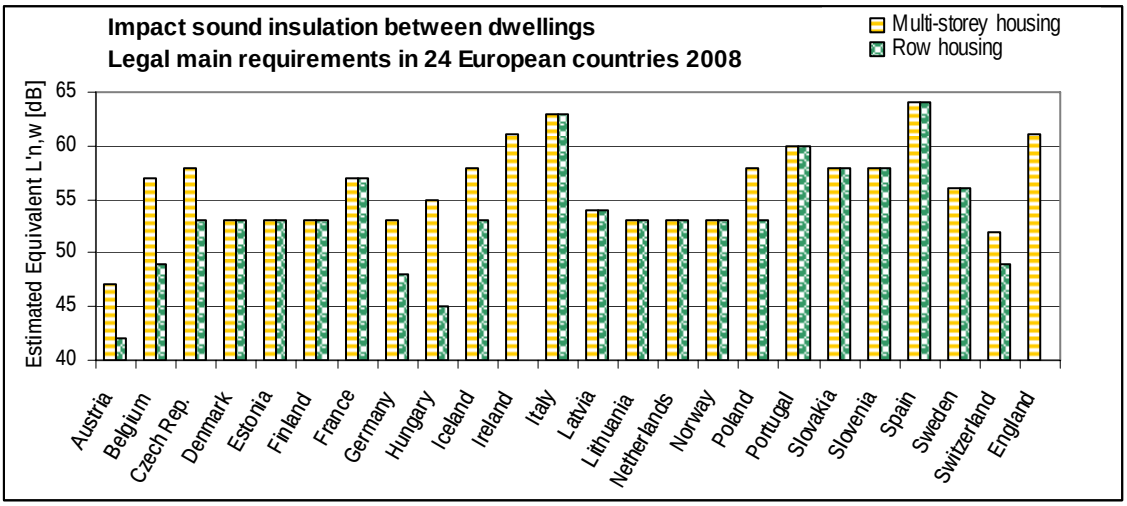

Figure 4 – Overview of requirements for impact sound level between dwellings (maximum values). Graphical presentation of estimated equivalent values of L'n,w.
Note: The equivalent values are estimates only, as exact conversion is not possible.

The differences in equivalent R'w values are up to about 5 dB for multi-storey housing and about 10 dB for row housing. Concerning impact sound insulation requirements, the max differences of equivalent L'n,w values are more than 15 dB for multi-storey housing and more than 20 dB for row housing. The strictest requirements are found in Austria. For more detailed - although not completely updated information - se [14] or [15].

4.2 Facade sound insulation

This paper focuses on sound insulation between dwellings, and only principles for facade sound insulation will be dealt with. Regulatory requirements for facade sound insulation can be expressed in more ways, directly or indirectly:

- Minimum facade sound insulation as a function of outdoor noise level (e.g. FR, DE, LT, NL, AT)
- Max indoor noise levels (e.g. DK, FIN, IS, NO, SE)
- Max "night event" levels - combined with other criteria (e.g. NO, SE)

All ways will lead to sound insulation requirements for the facade components. The needed facade sound insulation depends on the outdoor noise level and maximum indoor level. The outdoor noise levels are calculated based on the traffic data and conditions. Often, the traffic noise levels are available from authorities. The levels vary with positions, see Figure 4.

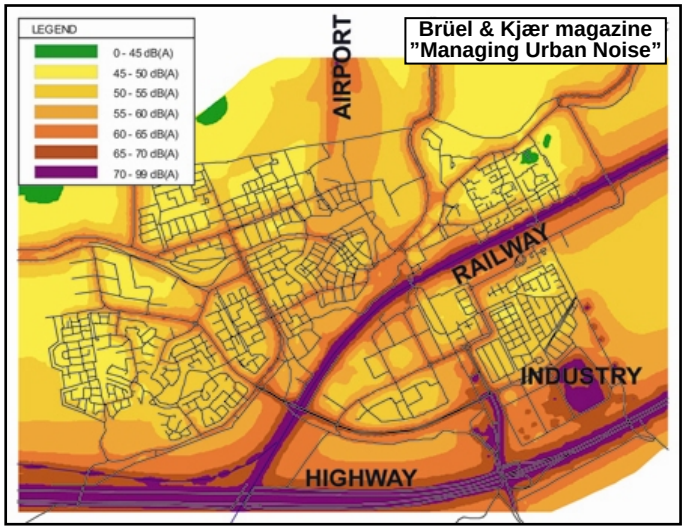

Figure 4 – Example of mapping of outdoor noise from road traffic, railways, airports and industry. The regulatory sound insulation requirement for facades depends on the outdoor level and thus of the position.

In general, requirements concern the facade and not single components. Thus the required window sound insulation has to be calculated based on the requirement for the facade and the areas and sound insulation performance for the facade components. .

Figure 5 – The required window sound insulation is calculated based on the facade requirement and the performance and areas of components.

5. Sound classification schemes in Europe – Class criteria

5.1 Class criteria for sound insulation between dwellings

As mentioned before, meeting legal requirements does not guarantee sufficient acoustic comfort, and for this reason several countries have introduced classification schemes, enabling specification of better acoustic conditions than required by the legal minimum requirements. Acoustic classification schemes exist in nine countries in Europe. France and Germany were the first countries to prepare and publish such schemes - 1993 and 1994, respectively. An overview of European classification schemes is given in Table 1.

The main criteria for airborne and impact sound insulation between dwellings are found in Tables 5 and 6. The schemes include several other criteria concerning sound insulation and noise levels, see references [1] to [9]. For lightweight buildings it is important that low-frequency spectrum adaptation terms (down to 50 Hz) according to [10] are included, implying a significantly improved correlation between subjective and objective sound insulation, see [12] and [13].

The main criteria for airborne and impact sound insulation internally in dwellings are found in [15].

Considering the nine classification schemes in Europe there are several differences:

- Descriptors used to describe sound insulation and noise criteria
- Number of quality classes and intervals between classes
- Use of low-frequency spectrum adaptation terms according to ISO 717:1996 [10]
- Sound insulation internally in dwellings
- Common or separate quality levels for multi-storey and row housing
- Balance between criteria for airborne and impact sound insulation
- Relation to legal requirements

The status of the classification schemes in relation to the legal requirements varies. In some countries there is no link between the building code and the classification standard. In other countries they are strongly "integrated" and the building code refers to a specific class in the classification standard rather than describing the requirements. In Finland, Norway, Sweden and Lithuania, Class C equals the legal requirements, and the Classes A and B define higher levels of acoustical comfort. With regard to sound insulation between dwellings, the Danish building regulations also refer to specific criteria in Class C, but do not require complete compliance with all class criteria. By referring to a class, a building code draws attention to the facts that the legal requirements are minimum requirements and that possibilities of voluntary specification and design for better acoustic quality exist. If a classification scheme is not linked to building regulations, its impact will be less strong.

The Nordic schemes are based on a common Nordic draft [16], following several investigations but due to linking to building regulations, the national schemes were finished and published at different times and are unfortunately not identical.

Table 5 – Airborne sound insulation between dwellings. Main criteria in sound classification schemes in Europe.

Airborne sound insulation between dwellings - Main class criteria in dB					
Country [3]	**Class A** **NL: Class 1** **DE: Class III** **FR: N/A**	**Class B** **NL: Class 2** **DE: Class II** **FR: QLAC**	**Class C** **NL: Class 3** **DE: Class I** **FR: QL**	**Class D** **NL: Class 4** **DE: N/A** **FR: N/A**	**Class E** **NL: Class 5** **DE: N/A** **FR: N/A**
DK	$R'_w + C_{50\text{-}3150} \geq 63$	$R'_w + C_{50\text{-}3150} \geq 58$	$R'_w \geq 55$	$R'_w \geq 50$	N/A
FI	$R'_w + C_{50\text{-}3150} \geq 63$	$R'_w + C_{50\text{-}3150} \geq 58$	$R'_w \geq 55$	$R'_w \geq 49$	N/A
IS	$R'_w + C_{50\text{-}3150} \geq 63$	$R'_w + C_{50\text{-}3150} \geq 58$	$R'_w \geq 55$ (1)	$R'_w \geq 50$	N/A
NO	$R'_w + C_{50\text{-}5000} \geq 63$	$R'_w + C_{50\text{-}5000} \geq 58$	$R'_w \geq 55$ (1)	$R'_w \geq 50$	N/A
SE	$R'_w + C_{50\text{-}3150} \geq 61$	$R'_w + C_{50\text{-}3150} \geq 57$	$R'_w + C_{50\text{-}3150} \geq 53$	$R'_w \geq 49$	N/A
LT	$R'_w + C_{50\text{-}3150} \geq 63$ or $D_{nT,w} + C_{50\text{-}3150} \geq 63$	$R'_w + C_{50\text{-}3150} \geq 58$ or $D_{nT,w} + C_{50\text{-}3150} \geq 58$	R'_w or $D_{nT,w} \geq 55$ (1)	R'_w or $D_{nT,w} \geq 52$	R'_w or $D_{nT,w} \geq 48$
NL*	$D_{nT,w} + C \geq 62$	$D_{nT,w} + C \geq 57$	$D_{nT,w} + C \geq 52$	$D_{nT,w} + C \geq 47$	$D_{nT,w} + C \geq 42$
DE** Multi [2]	H: $R'_w \geq 59$ V: $R'_w \geq 60$	H: $R'_w \geq 56$ V: $R'_w \geq 57$	H: $R'_w \geq 53$ V: $R'_w \geq 54$	N/A	N/A
DE** Row [2]	$R'_w \geq 68$	$R'_w \geq 63$	$R'_w \geq 57$	N/A	N/A
FR***	N/A	$D_{nT,w} + C \geq 56$	$D_{nT,w} + C \geq 53$	N/A	N/A

* Classes 1, 2, 3, 4, 5; ** Classes III, II, I; * Classes QLAC, QL
(1) Use of $C_{50\text{-}3150/5000}$ is recommended also in Class C
(2) Multi = Multi-storey housing; Row = Row housing; H = Horizontal; V = Vertical
(3) For references, see Table 1

Table 6 – Impact sound insulation between dwellings. Main criteria in sound classification schemes in Europe.

Impact sound insulation between dwellings - Main class criteria in dB					
Country [3]	**Class A** **NL: Class 1** **DE: Class III** **FR: N/A**	**Class B** **NL: Class 2** **DE: Class II** **FR: QLAC**	**Class C** **NL: Class 3** **DE: Class I** **FR: QL**	**Class D** **NL: Class 4** **DE: N/A** **FR: N/A**	**Class E** **NL: Class 5** **DE: N/A** **FR: N/A**
DK	$L'_{n,w} + C_{I,50\text{-}2500} \leq 43$	$L'_{n,w} + C_{I,50\text{-}2500} \leq 48$	$L'_{n,w} \leq 53$	$L'_{n,w} \leq 58$	N/A
FI	$L'_{n,w} \leq 43$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 43$	$L'_{n,w} \leq 49$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 49$	$L'_{n,w} \leq 53$ (1)	$L'_{n,w} \leq 63$	N/A
IS	$L'_{n,w} \leq 43$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 43$	$L'_{n,w} \leq 48$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 48$	$L'_{n,w} \leq 53$ (1)	$L'_{n,w} \leq 58$	N/A
NO	$L'_{n,w} \leq 43$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 43$	$L'_{n,w} \leq 48$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 48$	$L'_{n,w} \leq 53$ (1)	$L'_{n,w} \leq 58$	N/A
SE	$L'_{n,w} \leq 48$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 48$	$L'_{n,w} \leq 52$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 52$	$L'_{n,w} \leq 56$ $L'_{n,w} + C_{I,50\text{-}2500} \leq 56$	$L'_{n,w} \leq 60$	N/A
LT	$L'_{n,w} + C_{I,50\text{-}2500} \leq 43$	$L'_{n,w} + C_{I,50\text{-}2500} \leq 48$	$L'_{n,w} \leq 53$ (1)	$L'_{n,w} \leq 58$	$L'_{n,w} \leq 60$
NL*	$L'_{nT,w} + C_I \leq 43$	$L'_{nT,w} + C_I \leq 48$	$L'_{nT,w} + C_I \leq 53$	$L'_{nT,w} + C_I \leq 58$	$L'_{nT,w} + C_I \leq 63$
DE** Multi [2]	$L'_{n,w} \leq 39$	$L'_{n,w} \leq 46$	$L'_{n,w} \leq 53$	N/A	N/A
DE** Row [2]	$L'_{n,w} \leq 34$	$L'_{n,w} \leq 41$	$L'_{n,w} \leq 48$	N/A	N/A
FR***	N/A	$L'_{nT,w} \leq 52$ (QLAC)	$L'_{nT,w} \leq 55$ (QL)	N/A	N/A

* Classes 1, 2, 3, 4, 5; ** Classes III, II, I; * Classes QLAC, QL
(1) Use of $C_{I,50\text{-}2500}$ is recommended also in Class C
(2) Multi = Multi-storey housing; Row = Row housing; H = Horizontal; V = Vertical
(3) For references, see Table 1

5.2 Class criteria for facade sound insulation

Facade sound insulation criteria are described in [17] and partly in [18]. The schemes include several other criteria concerning sound insulation and noise levels. For complete information, see [1] to [9].

5.3 Further comments related to classification schemes

As an alternative or supplement to extensive classification schemes, some countries have defined a simple set of criteria for increased acoustical comfort, for example added in an annex to the document describing the legal requirements, thus reducing the need for a classification scheme. Such criteria are found in e.g. Austria [19] and Germany [20]. The Austrian criteria in [19] are described as improvements in dB compared with the legal minimum requirements: (1) For airborne sound insulation between dwellings and for airborne sound insulation of facades, an improvement of 3 dB is defined; (2) For impact sound insulation between dwellings, an improvement of 5 dB is required; (3) Noise levels limits for technical installations are reduced by 5 dB. Increased comfort criteria are also inherent in the Swiss regulations [21] and in the new Belgian acoustic requirements [22].

6. Conclusions

There are significant discrepancies between the European classification schemes for dwellings, among these descriptors, number of quality classes, intervals between classes, levels of classes and the status of the classification schemes in relation to the legal requirements. In some countries the building code and the classification standard are incoherent. In other countries they are strongly "integrated", implying that the building code refers to a specific class in the classification standard rather than describing the requirements.

The findings do not reflect a harmonised Europe. In the future, efforts should be made to harmonize sound insulation descriptors and preferably also class levels. National regulatory requirements are decided at a national level, and by harmonizing a classification scheme, each country could choose the class for requirements found appropriate to meet the expectations of the inhabitants.

For existing housing, measures may be needed to improve sound insulation. Sound insulation is not only a question of comfort, but also about health, cf. [23]. Furthermore, insufficient sound insulation may be the cause of conflicts between neighbours.

In order to gather information and share experience more systematically, a working group, EAA TC-RBA WG4 [24], has been established. In the future, this working group could advise on use of descriptors for sound insulation as well as choice of class for the legislation.

More noise sources - including neighbours’ activities - and an increased demand for high quality and comfort together with a trend towards light-weight constructions are contradictory and call for optimising building design and exchange experience.

The benefits of a harmonisation include facilitating the exchange of information and experience and development of design tools. Based on the experience, classification criteria might be adjusted and optimized.

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– Part 5: Field measurements of airborne sound insulation of facade elements and facades, 1998.
– Part 7: Field measurements of impact sound insulation of building elements, 1998.
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