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Acoustic classification of dwellings – A growing diversity of sound insulation descriptors in national schemes in Europe

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ABSTRACT

Acoustic classification schemes for dwellings exist in several countries in Europe, typically prepared and published as national standards. The schemes define quality classes intended to reflect different levels of acoustic comfort. The main criteria concern airborne and impact sound insulation between dwellings, facade sound insulation and service equipment noise. The schemes have been implemented and revised gradually since the early 1990s. However, due to lack of coordination, there are significant discrepancies, and new standards and revisions continue to increase the diversity in Europe. Descriptors, number of quality classes, denotations, class intervals, total range of classes and class levels vary – as well as the status in relation to regulations. The diversity in Europe is an obstacle for exchange of experience about constructions fulfilling different classes and thus for design and trade. The paper presents an updated overview of acoustic classification schemes in Europe and detailed information about the variety of descriptors applied for sound insulation between dwellings. The implications of interaction – or lack of interaction – between acoustic classification schemes and national acoustic regulations will be indicated and discussed. Finally, the main features of ISO/TS 19488 about acoustic classification of dwellings will be included in the comparative study of national schemes.

Keywords: Sound insulation, descriptors, acoustic classification, building regulations, housing

1. INTRODUCTION

In Europe, acoustic regulations for dwellings are included in building regulations in more than 30 countries, cf. [1]. In some countries, requirements have existed since the 1950s or even before, while in other countries, acoustic regulations came later or do not yet exist. However, complying with regulatory requirements does not guarantee satisfactory conditions for the occupants in dwellings, and since the early 1990s, several countries have developed and introduced acoustic classification schemes (abbreviated ACS in this paper) with classes intended to reflect different levels of acoustic protection and comfort, see illustration in Table 1. The ACS in Europe are national schemes, the majority being published by national standardization organizations. The schemes are very different due to lack of coordination between countries.

Table 1 – Illustration of acoustic quality classes using various, partly FICTIVE ranges and denotations.

	Acoustic quality classes						
☺ ☺ ☺ High acoustic protection and comfort	A	B	C	D	E	F	☹ ☹ ☹ Low acoustic protection and comfort
	III	II	I				
			a	b	c	d	
			I	II	III	IV	
		A	B	C	D		

In both acoustic regulations and ACS, limits relate to airborne and impact sound insulation, noise levels from traffic and service equipment as well as other acoustic and noise aspects, and limit values must be complied with in the completed building. This paper deals with airborne and impact sound

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insulation between dwellings in multi-storey housing. Test and rating methods are described in ISO 16283 [2] and ISO 717 [3], and estimation methods for acoustic performance of buildings in ISO 12354 [4], which are all so-called harmonized standards and thus implemented also as EN standards and as national standards in CEN countries.
In the following Sections are found overviews for Europe of acoustic classification schemes, airborne and impact sound insulation descriptors applied in ACS, sound insulation requirements in selected countries and use of low-frequency descriptors in regulations and ACS. Discussion, conclusions and recommendations are found in the last part of the paper.

2. ACOUSTIC CLASSIFICATION SCHEMES (ACS) IN EUROPE – HOUSING

Acoustic classification schemes (ACS) for dwellings exist in at least 14 countries in Europe. In Germany, there are two schemes, one published by VDI, the other by DEGA. Thus, there are in total 15 schemes [5]-[19] in Europe (and maybe more not known by the author of this paper). An overview of the schemes is found in Table 2. The schemes considered are those having minimum three acoustic classes. For each scheme listed, the class denotations, number of classes and relation to the national building code are indicated. The ISO Technical Specification ISO/TS 19488 [20] is added for comparison. For more information about the development of ISO/TS 19488, see [21]. Table 2 also includes numbers of acoustic classes below and above the national regulations. – A similar table was presented in [1], but Table 2 below has been extended with the new Spanish scheme UNE 74201 [16] and updated due to revisions of NS 8175 [8] and ÔNORM B 8115-5 [15] – and publishing of ISO/TS 19488 [20].

Table 2 – European schemes for acoustic classification of dwellings, [5]-[19], relation to building regulations and class information. ISO/TS 19488 (2021), [20], included for comparison.

Acoustic classification of dwellings - Schemes in Europe and relation to building regulations – Status May 2022

Coun-try	Year of publication	CS Reference (latest version)	Class denotations(1)	BR link to CS	BR ref. to CS & Comments	No. of classes	No. of classes > BR	No. of classes < BR
DK	2001 / 2007 / 2018	DS 490 (2018)	A / B / C / D / E / F	+	Class C	6	2	3
FI	2004	SFS 5907 (2004)	A / B / C / D	–	N/A (BR ~ Class C)	4	2	1
IS	2003 / 2011 / 2016	IST 45 (2016)	A / B / C / D	+	Class C	4	2	1
NO	1997–2019 (5 versions)	NS 8175 (2019) (9)	A / B / C / D	+ (9)	Class C (9)	4	~ 2	~ 1
SE	1996–2015 (4 versions)	SS 25267 (2015)	A / B / C (2) / D	–	N/A (See note (2))	4	2	1
LT	2003	STR 2.01.07 (2003)	A / B / C / D / E	+	Class C	5	2	2+npd
LV	2011/2015	LBN 016-15 (2015)	A / B / C / D	+	Class C	4	2	~ 0
IT	2010	UNI 11367 (2010)	I / II / III / IV	–	N/A (BR ~ Class III	4	2	1
DE	1994 / 2007 / 2012	VDI 4100 (2012) (3)	III / II / I	–	N/A (BR ~ Class I (2))	3	3	~ 0
DEGA	2009 / 2018	DEGA Empfehlung 103 (2018) (4)	A*/ A / B / C / D / E / (F)	–	N/A (BR ~ Class D (4))	6+npd	4	1+npd
AT (5)	2012 / 2021	ÖNORM B 8115-5 (2021)	A / B / C / D / (E)	–	N/A (BR ~ Class C (6))	5	~ 2	~ 2
ES	2021	UNE 74201 (2021)	A / B / C / D / E / (F) and npd	–	N/A (BR ~ Class D)	6+npd	3	2+npd
NL	1999	NEN 1070 (1999)	I / II / III / IV / V	–	N/A (BR ~ Class III)	5	2	2
PL	2017	PN-B-02151-5 (2017)	AQ-4 / AQ-3 / AQ-2 / AQ-1 / AQ-0	–	N/A (BR ~ Class AQ-0)	5	4	0
TR	2017	Noise Protection and sound insulation in Buildings (7)	A / B / C / D / E / F	+	Class C	6	2	3
ISO/TS	2021	ISO/TS 19488 (2021) (8)	A / B / C / D / E / F and npd	N/A	N/A	6+npd	N/A	N/A

Abbreviations: BR = Building Regulations (regulatory requirements); CS = Classification scheme

(1) Classes are indicated in descending order, i.e. the best class first. Denotations in brackets correspond to npd or that no limits have to fulfilled.
(2) SS 25267 (2015) does not include class C limits, but refers to criteria in the BR as class C.
(3) The revised version of VDI 4100 published in 2012 changed descriptors from R'_w and $L'_{n,w}$ to $D_{nT,w}$ and L'_{nT} (as had been discussed for years for the regulations), and class criteria were made stricter, i.e. above and regulations. After tightening of DIN 4109-1 in 2016, the basic criteria for the lowest class I for MS-housing are again similar to regulations, but VDI 4100 has additional criteria, e.g. on internal sound insulation.
(4) In addition to VDI 4100, the German Society of Acoustics (DEGA) has published a recommendation, DEGA-Empfehlung 103, "Schallschutz im Wohnungsbau – Schallschutzausweiz". For MS-housing, Class D criteria in general correspond to regulations, but there are additional criteria.
(5) The ACS defines alternative and additional criteria, the indicated information just being a part of one of the options.
(6) For row housing, BR ~ Class B. See also note (5).
(7) "Regulation on Protection of Buildings against Noise" www.resmigazete.gov.tr/eskiler/2017/05/20170531-7.htm (May 2017).
(8) Original proposal prepared by COST TU0901 in 2013. ISO/WI 19488 from 2014, ISO/TS in April 2021.
(9) The current building regulations (May 2022) still refers to NS 8175:2012, implying that the connection between BR and CS is currently unresolved.

From Table 2 it is seen that four of the five Nordic countries (FI, IS, NO, SE) and IT have one quality class below regulations, LT and ES have two classes + npd, AT and NL two classes, and DE (DEGA 103) 1+npd. DK and TR have three classes below regulations, implying a much higher chance of classifying older housing. DE (VDI 4100) and PL have none, thus following the original idea of acoustic classes to be only/mainly for specifying better acoustic conditions than regulations. To sum up briefly, the existing acoustic classification schemes do in general not include acoustic classes fitting all major parts of the existing housing stock, although an extension with lower classes for old housing could pave the road for a future acoustic labelling in a similar way as for the mandatory energy labelling.

3. SOUND INSULATION BETWEEN DWELLINGS: DESCRIPTORS IN ACS

Airborne and impact sound insulation descriptors applied in the national acoustic classification schemes listed in Table 2 are found in Tables 3 and 4. Limit values have not been inserted, but should be part of future studies. For airborne sound insulation, higher values mean better performance, for impact sound insulation, it is opposite, so lower values mean better performance.

Thus, for airborne sound insulation, limit values are in general minimum values to be complied with, and for impact sound insulation, limit values are in general max values. Exceptions are the lowest classes in Austria and Spain, where no limits must be complied with, see Tables 3 and 4.

Comparing the data from the classification schemes in Europe, see Table 2, detailed class criteria in [5]-[19] and overview of descriptors in Tables 3 and 4, significant differences are found, e.g. the following:

- Number of quality classes (3 to 6) and denotations. Note: "npd" not counted as a class.
- Descriptors used for sound insulation criteria.
- Use of low-frequency spectrum adaptation terms according to ISO 717:2020.
- Intervals between classes.
- Range of quality classes (~ 8 to 23 dB for airborne, ~ 14 to 30 dB for impact) and position.
- Relation to regulatory requirements.
- Procedure/rules for class assignment based on sample measurements.
- Verification of class, which could be by field measurements only or a combination of calculations, visual inspections, and field measurements.
- Subjective descriptions of acoustic conditions for various types of sounds and neighbour noises.

Other relevant comparisons between the national acoustic classification schemes could be e.g. about: Sound insulation internally in dwellings; Sound absorption in stairwells; Outdoor noise levels; Classification certificates.

Table 3 – Airborne sound insulation between dwellings. Descriptors in acoustic classification schemes in Europe. References [5]-[19]. ISO/TS 19488 (2021), [20], has been included for comparison.

Airborne sound insulation between dwellings - Descriptors for class (1) criteria – Status May 2022							
Country (1)	**Class A** NL, IT: I DE/PL: III/AQ-4	**Class B** NL, IT: II DE/PL: II/AQ-3	**Class C** NL, IT: III DE/PL: I/AQ-2	**Class D** NL, IT: IV PL: AQ-1	**Class E** NL: V PL: AQ-0	**Class F**	**BR reference to ACS**
DK	$R'_w + C_{50\text{-}3150}$	$R'_w + C_{50\text{-}3150}$	R'_w	R'_w	R'_w	R'_w	Class C
FI	$R'_w + C_{50\text{-}3150}$	$R'_w + C_{50\text{-}3150}$	R'_w	R'_w	N/A	N/A	None (BR ~ Class C)
IS	$R'_w + C_{50\text{-}3150}$	$R'_w + C_{50\text{-}3150}$	R'_w (2)	R'_w	N/A	N/A	Class C
NO	$R'_w + C_{50\text{-}5000}$	$R'_w + C_{50\text{-}5000}$	$R'_w + C_{50\text{-}5000}$	R'_w	N/A	N/A	BR refers to Class C in NS 8175:2012
SE	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w} + C_{50\text{-}3150}$	$(D_{nT,w} + C_{50\text{-}3150})$	$D_{nT,w} + C$	N/A	N/A	None (Class C = BR)
LT	$R'_w + C_{50\text{-}3150}$ or $D_{nT,w} + C_{50\text{-}3150}$	$R'_w + C_{50\text{-}3150}$ or $D_{nT,w} + C_{50\text{-}3150}$	R'_w or $D_{nT,w}$ (5)	R'_w or $D_{nT,w}$	R'_w or $D_{nT,w}$	N/A	Class C
LV	$R'_w + C_{50\text{-}3150}$	$R'_w + C_{50\text{-}3150}$	R'_w	R'_w	N/A	N/A	Class C
IT	R'_w	R'_w	R'_w	R'_w	N/A	N/A	None (BR ~ Class III)
DE (3)	$D_{nT,w}$	$D_{nT,w}$	$D_{nT,w}$	N/A	N/A	N/A	None (BR < Class I)
DEGA (4)	R'_w	R'_w	R'_w	R'_w	R'_w	npd	None (BR ~ Class D)
AT (5)	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w}$	$((D_{nT,w}))$ (7)	N/A	None (BR ~ Class C(6))
ES (8)	$D_{nT,A}$	$D_{nT,A}$	$D_{nT,A}$	$D_{nT,A}$	$D_{nT,A}$	$((D_{nT,A}))$ (7)	None (BR ~ Class D)
NL	$D_{nT,w} + C$	$D_{nT,w} + C$	$D_{nT,w} + C$	$D_{nT,w} + C$	$D_{nT,w} + C$	N/A	None (BR ~ Class III)
PL	$R'_w + C_{tr}$	$R'_w + C_{tr}$	$R'_w + C$	$R'_w + C$	$R'_w + C$	N/A	None (Class AQ-0 = BR)
TR	$D_{nT,w} + C$	$D_{nT,w} + C$	$D_{nT,w} + C$	$D_{nT,w} + C$	$D_{nT,w} + C$	$D_{nT,w} + C$	Class C
ISO/TS (9)	$D_{nT,50}$	$D_{nT,50}$	$D_{nT,A}$	$D_{nT,A}$	$D_{nT,A}$	$D_{nT,A}$	N/A

Abbreviations: BR = Building Regulations (regulatory requirements); ACS = Acoustic Classification Scheme.
(1) For references to classification schemes, see separate information. Classes indicated in descending order, i.e. the best class first.
(2) Use of $C_{50\text{-}3150}$ is recommended also in Class C. If applied, the limit value may be reduced, see references.
(3) The classification scheme VDI 4100 has separate class criteria for multi-storey and row housing, the latter being 9-10 dB stricter.
(4) In addition, there is another scheme, DEGA-Empfehlung 103 with 6 classes A*-E and class F = npd, descriptor R'_w applied. Due to lack of space in the table, Class A* is not included.
(5) The ACS defines alternative and additional criteria, the information in the table just being a part of one of the options.
(6) For row housing, BR ~ Class B. See also note (5).'
(7) Double brackets (( )) indicate that there is no lower limit to be complied with like for the stricter classes.
(8) $D_{nT,A} \approx D_{nT,w} + C_{100\text{-}5000}$. Note that the definition here is different than that applied in ISO/TS 19488, see note (9).
(9) The descriptors indicated are from ISO/TS 19488:2021. $D_{nT,50} = D_{nT,w} + C_{50\text{-}3150}$; $D_{nT,A} = D_{nT,w} + C$

Table 4 – Impact sound insulation between dwellings. Descriptors in acoustic classification schemes in Europe. References [5]-[19]. ISO/TS 19488 (2021), [20], has been included for comparison.

Impact sound insulation between dwellings – Descriptors for class (1) criteria - Status May2022							
Country(1)	Class A NL, IT: I DE/PL: III/AQ-4	Class B NL, IT: II DE/PL: II/AQ-3	Class C NL, IT: III DE/PL: I/AQ-2	Class D NL, IT: IV PL: AQ-1	Class E NL: V PL: AQ-0	Class F	BR reference to ACS
DK	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$	$L'_{n,w}$	$L'_{n,w}$	$L'_{n,w}$	Class C
FI	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ (5)	$L'_{n,w}$	N/A	N/A	None (BR > Class C)
IS	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ (5)	$L'_{n,w}$	N/A	N/A	Class C
NO	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$	N/A	N/A	BR refers to Class C in NS 8175:2012
SE	$L'_{nT,w}$ and $L'_{nT,w} + C_{I,50\text{-}2500}$	$L'_{nT,w}$ and $L'_{nT,w} + C_{I,50\text{-}2500}$	($L'_{nT,w}$ and $L'_{nT,w} + C_{I,50\text{-}2500}$)	$L'_{nT,w}$	N/A	N/A	None (Class C = BR)
LT	$L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ (2)	$L'_{n,w}$	$L'_{n,w}$	N/A	Class C
LV	$L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$	$L'_{n,w}$	N/A	N/A	Class C
IT	$L'_{n,w}$	$L'_{n,w}$	$L'_{n,w}$	$L'_{n,w}$	N/A	N/A	None (BR ~ Class III)
DE (3)	$L'_{nT,w}$	$L'_{nT,w}$	$L'_{nT,w}$	N/A	N/A	N/A	None (BR ~ Class I)
DEGA (4)	$L'_{n,w}$	$L'_{n,w}$	$L'_{n,w}$	$L'_{n,w}$	$L'_{n,w}$	npd	None (BR ~ Class D)
AT (5)	$L'_{nT,w} + C_{I,50\text{-}2500}$	$L'_{nT,w} + C_{I,50\text{-}2500}$	$L'_{nT,w} + C_{I,50\text{-}2500}$	$L'_{nT,w}$	(($L'_{nT,w}$)) (7)	N/A	None (BR ~ Class C(6))
ES	$L'_{nT,w}$	$L'_{nT,w}$	$L'_{nT,w}$	$L'_{nT,w}$	$L'_{nT,w}$	(($L'_{nT,w}$)) (7)	None (BR ~ Class D)
NL	$L'_{nT,w} + C_I$	$L'_{nT,w} + C_I$	$L'_{nT,w} + C_I$	$L'_{nT,w} + C_I$	$L'_{nT,w} + C_I$	N/A	None (BR ~ Class III)
PL	$L'_{n,w}$	$L'_{n,w}$	$L'_{n,w}$	$L'_{n,w}$	$L'_{n,w}$	N/A	None (Class AQ-0 =BR)
TR	$L'_{nT,w}$	$L'_{nT,w}$	$L'_{nT,w}$	$L'_{nT,w}$	$L'_{nT,w}$	$L'_{nT,w}$	Class C
ISO/TS (8)	$L'_{nT,w}$ and $L'_{nT,50}$	$L'_{nT,w}$ and $L'_{nT,50}$	$L'_{nT,w}$	$L'_{nT,w}$	$L'_{nT,w}$	$L'_{nT,w}$	N/A

Abbreviations: BR = Building Regulations (regulatory requirements); ACS = Acoustic Classification Scheme.
(1) For references to classification schemes, see separate information. Classes indicated in descending order, i.e. the best class first.
(2) Use of $C_{I,50\text{-}2500}$ is recommended also in Class C.
(3) The classification scheme VDI 4100 has separate class criteria for multi-storey and row housing, the latter being 5 dB stricter.
(4) In addition, there is another scheme, DEGA-Empfehlung 103 with 6 classes A*-E and class F = npd, descriptor $L'_{n,w}$ applied. Due to lack of space in the table, Class A* is not included.
(5) The ACS defines alternative and additional criteria, the information in the table just being a part of one of the options.
(6) For row housing, BR ~ Class B. See also note (5).
(7) Double brackets (( )) indicate that there is no upper limit to be complied with like for the stricter classes.
(8) The descriptors indicated are from ISO/TS 19488:2021. $L'_{nT,50} = L'_{nT,w} + C_{I,50\text{-}2500}$.

While Tables 3-4 do not present limit values, such limits have been included in some of the previous studies, e.g. in 2020 for the Nordic countries, cf. [22], and in 2012, see [23], for 10 of the 15 schemes included in Tables 2-4. Tables with descriptors for 2018 are found in [24]. Comparing the changes over time shows a growing diversity, not only for descriptors.

Focus in most of the acoustic classification schemes have been to provide quantitative descriptions about limits and methods. Few of them, e.g. [13], [14] and [15], provide qualitative descriptions of acoustic conditions, although such information would be useful for all groups of users. In the below Table 5 is found a quite simple description of classes in DS 490 related to occupants' expected satisfaction.

Table 5 – Occupants' expected satisfaction for different acoustic classes according to DS 490:2018 [5]. Summary based on information in DS 490.

Sound insulation between dwellings Main class criteria A-F in DS 490:2018		
Class	Airborne	Impact
A	$R'_w + C_{50\text{-}3150} \geq 63$ dB	$L'_{n,w} \leq 43$ dB and $L'_{n,w} + C_{I,50\text{-}2500} \leq 43$ dB
B	$R'_w + C_{50\text{-}3150} \geq 58$ dB	$L'_{n,w} \leq 48$ dB and $L'_{n,w} + C_{I,50\text{-}2500} \leq 48$ dB
C	$R'_w \geq 55$ dB	$L'_{n,w} \leq 53$ dB
D	$R'_w \geq 50$ dB	$L'_{n,w} \leq 58$ dB
E	$R'_w \geq 45$ dB	$L'_{n,w} \leq 63$ dB
F	$R'_w \geq 40$ dB	$L'_{n,w} \leq 68$ dB
Reference: DS 490:2018 "Lydklassifikation af boliger" (Sound classification of dwellings)		

Characteristics of DS 490 sound classes for dwellings and occupants' expected evaluation Information from DS 490:2018		
Sound class descriptions	Good or very good	Poor
Excellent acoustic conditions. Occupants will be disturbed only occasionally by sound or noise.	> 90 %	
Significant improvement compared to minimum in class C. Occupants may be disturbed sometimes.	70-85 %	< 10 %
Sound class intended as the minimum for new buildings.	50-65 %	< 20 %
Sound class intended for older buildings with less satisfactory acoustic conditions, e.g. for renovated dwellings.	30-45 %	25-40 %
Sound class intended for older buildings with unsatisfactory acoustic conditions.	10-25 %	45-60 %
Sound class intended for older buildings with clearly unsatisfactory acoustic conditions.	< 5 %	65-80 %
Note: Within each sound class, the percentage of satisfied or dissatisfied occupants may depend on the type of criterion. The grouping is mainly based on the subjective assessments of airborne and impact sound from adjacent dwellings.		

4. SOUND INSULATION BETWEEN DWELLINGS: EXAMPLES REQUIREMENTS

A comparative study of airborne and impact sound insulation descriptors and requirements for multi-storey housing in 35 countries in Europe was carried out in 2019 and findings presented in [1], which includes both limit values ([1], Tables 2-3) and graphical presentations ([1], Figures 1-2). Note: There is at least one typo and a mistake in Table 3 in [1], since Finland applies a descriptor based on $L'_{nT,w}$ (not $L'_{n,w}$) and Ireland had/has a requirement $L'_{nT,w} \leq 58$ dB (not 62 dB).

The results clearly indicate significant discrepancies in descriptors and requirements for dwellings. An overview of number of countries with various sound insulation descriptors is found in Table 6 below (copied from [1]) for 31 countries in Europe (since 4 of the 35 countries do not have such regulations),. The dominant descriptors are clearly R'_w and $L'_{n,w}$, although there has been a trend during the last decade towards descriptors based on $D_{nT,w}$ and $L'_{nT,w}$ as e.g. in Sweden and Finland, see [22].

Table 6 – Sound insulation between dwellings: Number of countries applying various descriptors for regulations in Europe. The table is a copy from [1].

Sound insulation descriptors applied for regulatory requirements between dwellings in 31 countries in Europe. Status April 2019.			
Airborne sound		Impact sound	
No. of countries	Descriptor	No. of countries	Descriptor
15	R'_w	17	$L'_{n,w}$
7	$D_{nT,w}$	9	$L'_{nT,w}$
3	$R'_w + C$	2	$L'_{nT,w} + C_I$
3	$D_{nT,w} + C$	2	$L'_{nT,w} + C_{I,50\text{-}2500}$
1	$D_{nT,w} + C_{50\text{-}3150}$	1	L'_w
1	$D_{nT,A}$ ($\approx D_{nT,w} + C_{100\text{-}5000}$)	?	Variants
1	$D_{nT,w} + C_{tr}$	?	Recommendations
?	Variants	?	Special rules
?	Recommendations		
?	Special rules		

To the author's best knowledge, there have not been changes in regulations between April 2019 and May 2022. Nevertheless, it is found relevant to show a table with selected countries, see Table 7-8. Included are primarily those countries having quite strict requirements and (except for Belgium) ACS, implying potential learning about construction details fulfilling high requirements and classes with LF-terms. References to building regulations for the 8 countries are [25-29] for the Nordic countries and [30-32] for Austria, Belgium and Germany. Of special interest are how the current LF-recommendations, cf. Tables 7-9, and the challenges related to wooden buildings will be dealt with in the future.

Table 7 – Airborne sound insulation between dwellings. Main requirements in 8 selected countries (1)

Requirements (1) Status May 2022		Multi-storey housing	Comments
Country	**Descriptor (2)**	**Req. [dB]**	**See notes below table**
Austria	$D_{nT,w}$	≥ 55	(3)
Belgium	$D_{nT,w}$	≥ 54	(3),(7)
Denmark	R'_w	≥ 55	(6)
Finland	$D_{nT,w}$	≥ 55	
Germany	R'_w	≥ 53	(3),(5)
Iceland	R'_w	≥ 55	(4)
Norway	R'_w	≥ 55	(4),(8)
Sweden	$D_{nT,w} + C_{50\text{-}3150}$	≥ 52	

Notes
(1) Overview information only. Detailed requirements and conditions are found in the building codes.
(2) No generally applicable conversion between the different descriptors exists, as the relations depend on characteristics of rooms and constructions. Exact conversion can only be made in specific cases.
(3) In AT, BE, DE stricter limits apply for row housing.
(4) Use of $R'_w + C_{50\text{-}5000}$ recommended in NO and $R'_w + C_{50\text{-}3150}$ in IS. If applied, the limit value may be reduced, see regulations.
(5) Horizontal, requirement for vertical is 1 dB higher.
(6) For light-weight constructions (walls ≤ 100 kg/m²; floors ≤ 250 kg/m²) is recommended to fulfil also $R'_w + C_{50\text{-}3150} \geq 53$ dB.
(7) Under revision. Stricter requirements expected later in 2022.
(8) Under revision. In Norway, the acoustic regulations refer to NS 8175:2012, cf. limits in the table above. However, a revised NS 8175 was published in 2019, but still not referred to in the regulations.

Table 8 – Impact sound insulation between dwellings. Main requirements in 8 selected countries (1)

Requirements (1) Status May 2022		Multi-storey housing	Comments
Country	**Descriptor (2)**	**Req. [dB]**	**See notes below table**
Austria	$L'_{nT,w}$	≤ 48	(3)
Belgium	$L'_{nT,w}$	≤ 58	(3),(7),(8)
Denmark	$L'_{n,w}$	≤ 53	(6)
Finland	$L'_{nT,w} + C_{I,50\text{-}2500}$	≤ 53	
Germany	$L'_{n,w}$	≤ 50	(3)
Iceland	$L'_{n,w}$	≤ 53	(4)
Norway	$L'_{n,w}$	≤ 53	(4),(9)
Sweden	$L'_{nT,w} + C_{I,50\text{-}2500}$	≤ 56	(5)

Notes
(1) Overview information only. Detailed requirements and conditions are found in the building codes.
(2) No generally applicable conversion between the different descriptors exists, as the relations depend on characteristics of rooms and constructions. Exact conversion can only be made in specific cases.
(3) In AT, BE, DE stricter limits apply for row housing.
(4) Recommended that the same criteria are fulfilled by $L'_{n,w} + C_{I,50\text{-}2500}$.
(5) The same criteria shall also be fulfilled by $L'_{nT,w}$.
(6) For light-weight constructions (floors ≤ 250 kg/m²) is recommended to fulfil also $L'_{n,w} + C_{I,50\text{-}2500} \leq 53$ dB.
(7) From "non-bedrooms" outside the dwelling to a bedroom ≤ 54 dB is required.
(8) Under revision. Stricter requirements expected later in 2022.
(9) Under revision. In Norway, the acoustic regulations refer to NS 8175:2012, cf. limits in the table above. However, a revised NS 8175 was published in 2019, but still not referred to in the regulations.

5. ISO 717 LF SOUND INSULATION DESCRIPTORS IN REGULATIONS AND ACS

The history of ISO 717 sound insulation descriptors is described in [24] and [33-34], and no changes in spectrum adaptation terms were made in the latest version from 2020. In many European countries, the need for including low frequencies appropriately in rating of construction performance has been increasingly acknowledged by the building industry due to experience and surveys pointing in that direction, see e.g. [35] and [36]. Impact sound is clearly the most disturbing/annoying neighbour noise, not least in light-weight buildings. Thus, there is a high need for good prediction models, particularly for wooden buildings. However, due to high data uncertainties for wooden materials and products, the ISO 12354 methods for calculation of airborne and impact sound insulation between rooms have shortcomings, but development efforts are done in an ISO WG to improve applicability for CLT timber constructions.

A summary of low-frequency findings in the comparative studies of descriptors in regulations, recommendations and classification schemes in Europe is found in Table 9. It is seen that 8 of 14 countries listed in Table 2 have included LF-descriptors in the upper classes in acoustic classification schemes (for details, see Tables 3-4). Two countries have applied LF descriptors in mandatory airborne and/or impact sound insulation requirements, and further four countries have made recommendations, for one of these countries (DK) related to light-weight constructions only, see Tables 7-8.

Table 9 – Number of countries in Europe using ISO 717 low-frequency sound insulation descriptors.

LF descriptors in acoustic regulations, recommendations and acoustic quality classes in Europe. Status May 2022.			
Number of countries	Acoustic regulations		Acoustic quality classes
	LF mandatory	LF recommended	
Airborne	1 (SE)	3 (IS, NO. LT) + 1 (1)	8 (2)
Impact	2 (SE & FI)	3 (IS, NO. LT) + 1 (1)	8 (2)
(1) In DK, it is recommended using LF-descriptors in case of light-weight constructions (walls < 100 kg/m², floors < 250 kg/m²), [21].			
(2) Classes A and B in DK, FI, IS, NO, SE, LT, LV, AT: LF-descriptors included.			

In general, there is an increasing attention to the LF-performance. In Germany, LF performance is not included in requirements [32] or in VDI 4100 [13], but due to strong customer requests, a German book [37] about sound insulation of wooden buildings have LF data included. In [36], describing research results from Swedish case studies about sound insulation of wooden housing, it is recommended to make the Swedish impact requirements $L'_{nT,w,50}$ stricter and for lightweight/wooden housing to go further down to 25 Hz, i.e. design for $L'_{nT,w,25}$.

6. SUMMARY & RECOMMENDATIONS

The national acoustic classification schemes (ACS) in Europe differ significantly concerning sound insulation descriptors, numbers/levels of classes and relation to building regulations etc., see Sections 2-3. The diversity of descriptors is high and growing, and the former direct relations to regulations have disappeared in some countries. For example, regulations in four (DK, IS, NO, SE) of the five Nordic countries in 2012 [23] referred to class C in the national ACS, and FI did not have such reference, but the limit values were the same. In 2020, ACS descriptors had changed in three of the five countries, and relation to regulations reduced [22].

Building regulations typically specify only minimum requirements for acoustic conditions for new dwellings, cf. [1]. It seems obvious that acoustic classes are relevant both for higher comfort and protection in new housing as well as for existing housing before renovation by having classes suitable for older housing with a performance far below current regulations, thus making the gap to regulations visible.

Recommendations for further activities/initiatives/studies

- In each national ACS: Make a clear relation/interaction between BR and ACS, see [1] and this paper.
- ISO/TS 19488 [20] was developed based on experiences from many countries. The ISO/TS could be developed further, see topics in [21], and some countries could get useful input to national BR and ACS.
- Number of quality classes in ACS should be adapted to enable labelling of the whole national housing stock.
- Spectrum adaptation terms in ISO 717 [3]: For impact sound, prepare for potential new (LF) descriptors suitable for lightweight constructions (ISO 717-2). For airborne sound (ISO 717-1), suggest removing terms up to 5 kHz, thus reducing number of terms to the half.
- Add information about subjective perception/audibility for various sound sources like in DE [13-14] (VDI & DEGA103) and AT [15]. Examples of neighbour noise sources are also found in [38].

Harmonization is still good ☺, see [20, 21, 39]. In the end, acoustic classification and regulations shall serve the needs of people, who need privacy, comfort and protection in their homes during various activities.

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