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Acoustic classification schemes in Europe – Applicability for new, existing and renovated housing

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The first acoustic classification schemes for dwellings were published in the 1990'es as national standards with the main purpose to introduce the possibility of specifying easily stricter acoustic criteria for new-build than the minimum requirements found in building regulations. Since then, more countries have introduced acoustic classification schemes, the first countries updated more times and some countries introduced acoustic classification also for other building categories. However, the classification schemes continued to focus on new buildings and have in general limited applicability for existing buildings from before implementation of acoustic regulations, typically in the 1950'es or later.
The paper will summarize main characteristics, differences and similarities of the current national quality classes for housing in ten countries in Europe. In addition, the status and challenges of the international scheme for classification of dwellings under development in ISO/TC43/SC2 will be explained. One of several key characteristics of the proposal is a wide range of classes, implying applicability to a major part of the existing housing stock in Europe, thus enabling acoustic labelling like energy labelling. Consequently, acoustic quality could be visible and initiate consideration of improvement of acoustic conditions, when renovating housing as an integrated part of the renovation process.

1 Introduction

Acoustic regulations for housing specify minimum requirements aiming at protecting health for "normal" people with "normal" neighbours. Such regulations exist in most countries in Europe, cf. [1, 2, 3], and define criteria for acoustical conditions in new housing. However, complying with regulatory requirements does not guarantee satisfactory conditions for the occupants, and since the mid 1990'es, several countries have developed and introduced acoustic classification schemes with classes reflecting different levels of acoustical comfort/protection. The purpose is to make it easier for developers to specify and for users to require a standardized acoustic quality better than the quality defined by regulations. Defining in this paper a classification scheme as having minimum three classes, there are acoustic classification schemes in ten countries in Europe, see illustration in Figure 1. This paper describes the main characteristics of the schemes focusing on comparing the sound insulation descriptors and quality class ranges with the national acoustic regulations for dwellings and discussing the applicability for the housing stock, focusing on multi-storey housing.

Figure 1: Acoustic classification schemes in Europe have been published by national standardization organizations since the 1990'es. An overview of schemes is found in Table 1.

2 Acoustic classification schemes for housing – Overview schemes and sound insulation descriptors in Europe

An overview of existing national acoustic classification schemes for dwellings [4-13] is found in Table 1. For each scheme listed, the class denotations and the relation to the national building code are indicated. Information about an international proposal is found in [14] and [15]. Tables with specific main class criteria for airborne and impact sound insulation are found in [16] although some data need to be updated.

Table 1: European schemes for acoustic classification of dwellings and relation to building codes. A proposal prepared by COST TU0901 and approved as WI in ISO has been included for comparison. Status April 2016.

Acoustic classification of dwellings
Overview schemes in Europe and relation to building codes – Status April 2016

Coun-try	Year of publication	CS Reference (latest version)		Class denotations(1)	BC link to CS	BC Reference to CS	Comments
DK	2001/2007	DS 490 (2007)	[4]	A / B / C / D	+	Class C	
FI	2004	SFS 5907 (2004)	[5]	A / B / C / D	–	N/A	BC = Class C
IS	2003/2011/2016	IST 45 (2016)	[6]	A / B / C / D	+	Class C	
NO	1997/2005/2008/2012	NS 8175 (2012)	[7]	A / B / C / D	+	Class C	
SE	1996/1998/2004/2015	SS 25267 (2015)	[8]	A / B / C / D	–	N/A	See note (4)
LT	2003	STR 2.01.07 (2003)	[9]	A / B / C / D / E	+	Class C	
IT	2010	UNI 11367 (2010)	[10]	I / II / III / IV	–	N/A	BC ~ Class III
DE	1994/2007/2012	VDI 4100 (2012)(2),(3)	[11]	III / II / I	–	N/A	
AT	2012	ÖNORM B 8115-5 (2012)	[12]	A / B / C / D / E	–	N/A	BC = Class C
NL	1999	NEN 1070 (1999)	[13]	I / II / III / IV / V	–	N/A	BC ~ Class III
ISO/WI	TU0901 (2013) ISO/WI since 2014	ISO/WI 19488 See [14], [15]	[14]	A / B / C / D / E / F and npd	N/A	N/A	See note (5)

Abbreviations: BC = Building Code (regulatory requirements); CS = Classification scheme
(1) Classes are indicated in descending order, i.e. the best class first.
(2) In addition to VDI 4100, the German Society of Acoustics (DEGA) has published a recommendation (DEGA-Empfehlung 103, "Schallschutz im Wohnungsbau – Schallschutzausweiz", DEGA, March 2009) for acoustic labelling of dwellings. The system has seven classes A*-F and a colour code.
(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. Also the class criteria were made stricter, and all classes are now stricter than regulations (before the lowest class corresponded to regulations).
(4) SS 25267 (2015) does not include class C criteria, but refers to values in the BC as class C.
(5) Proposal prepared by COST TU0901 in 2013. ISO/WI 19488 from 2014, see [15], ISO/CD expected in 2016.

The airborne and impact sound insulation descriptors applied in the ten classification schemes [4-13] are found in Tables 2-3, and the quality class ranges and regulations are seen in the diagrams in Figures 2-3. Comparing the data from the ten classification schemes in Europe, see Tables 1-3, Figures 2-3 and detailed class criteria in [4-13], several differences are found:

- Number of quality classes (3 to 5) and denotations (see table 1).
- Range of quality classes (8-20 dB for airborne, 12-20 dB for impact) and position, see Figures 2-3.
- Intervals between classes (3-6 dB for airborne, 2-10 dB for impact).
- Descriptors used for sound insulation criteria, see Tables 2-3.
- Use of low-frequency spectrum adaptation terms according to ISO 717:2013 [17]
- Common or separate quality levels for multi-storey and row housing, see Tables 2-3.
- Relation to regulatory requirements, see tables 1-3 and Figures 2-3.

The majority of the classification schemes include criteria for sound insulation internally in dwellings, see [4-13] and [18]. When comparing the information in Table 1, some schemes may appear similar, e.g. NL and IT, but they are very different. Even the Nordic schemes originating in the same INSTA-proposal [19] are more different than they appear from Table 1, see [18]. Due to lack of coordination between countries, the schemes in Europe are very different, thus impeding exchange of experience and causing trade barriers. When proceeding with harmonization efforts, it is important to analyze differences between existing schemes. For [14], the main discussion issue for the time being is the frequency range, as it on one hand is recognized that for some constructions a frequency range down to 50 Hz would be appropriate, but on the other hand several countries prefer 100 Hz as the lower limit due to measurement uncertainty.

Table 2: Airborne sound insulation between dwellings. Descriptors in acoustic classification schemes in Europe.

Airborne sound insulation between dwellings - Descriptors for class criteria - Status April 2016							
Country (1)	**Class A** **NL, IT: Class I** **DE: Class III**	**Class B** **NL, IT: Class II** **DE: Class II**	**Class C** **NL, IT: Class III** **DE: Class I**	**Class D** **NL, IT: Class IV** **DE: N/A**	**Class E** **NL: Class V** **IT, DE: N/A**	**Class F**	**BC reference to CS**
DK	$R'_w + C_{50\text{-}3150}$	$R'_w + C_{50\text{-}3150}$	R'_w	R'_w	N/A	N/A	Class C
FI	$R'_w + C_{50\text{-}3150}$	$R'_w + C_{50\text{-}3150}$	R'_w	R'_w	N/A	N/A	None (BC = Class C)
IS	$R'_w + C_{50\text{-}3150}$	$R'_w + C_{50\text{-}3150}$	R'_w (4)	R'_w (4)	N/A	N/A	Class C
NO	$R'_w + C_{50\text{-}5000}$	$R'_w + C_{50\text{-}5000}$	R'_w (4)	R'_w (4)	N/A	N/A	Class C
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 = BC)
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 $D_{nT,w}$ (1)	R'_w or $D_{nT,w}$	R'_w or $D_{nT,w}$	N/A	Class C
IT*	R'_w	R'_w	R'_w	R'_w	N/A	N/A	None (BC ~ Class III
DE** (2)	$D_{nT,w}$	$D_{nT,w}$	$D_{nT,w}$	N/A	N/A	N/A	None (BC < Class I)
AT (3)	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w}$	$D_{nT,w}$	$D_{nT,w}$	N/A	None (BC = Class C)
NL***	$D_{nT,w} + C$	$D_{nT,w} + C$	$D_{nT,w} + C$	$D_{nT,w} + C$	$D_{nT,w} + C$	N/A	None (BC ~ Class III)
ISO/WI (5)	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w} + C_{50\text{-}3150}$	N/A

* Classes I, II, III, IV; ** Classes III, II, I; *** Classes I, II, III, IV, V
(1) For references to the standards describing the classification schemes, see Table 1.
(2) The classification scheme has separate criteria for multi-storey and row housing, the latter being 9-10 dB stricter.
(3) For row housing, Class C has a special 5 dB stricter criterion to match the building regulations; the class is denoted $C_{R.}$
(4) Use of $C_{50\text{-}3150/5000}$ is recommended also in Class C. If applied, the limit value may be reduced, see references.
(5) The descriptors indicated are those from the ISO/WI 19488. The frequency range is currently discussed.

Table 3: Impact sound insulation between dwellings. Descriptors in acoustic classification schemes in Europe.

Impact sound insulation between dwellings – Descriptors for class criteria - Status April 2016							
Country(1)	**Class A** **NL, IT: Class I** **DE: Class III**	**Class B** **NL, IT: Class II** **DE: Class II**	**Class C** **NL, IT: Class III** **DE: Class I**	**Class D** **NL, IT: Class IV** **DE: N/A**	**Class E** **NL: Class V** **IT, DE: N/A**	Class F	BC reference to CS
DK	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$	$L'_{n,w}$	N/A	N/A	Class C
FI	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ (1)	$L'_{n,w}$ (4)	N/A	N/A	None (BC = Class C)
IS	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ (1)	$L'_{n,w}$ (4)	N/A	N/A	Class C
NO	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ (1)	$L'_{n,w}$ (4)	N/A	N/A	Class C
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 = BC)
LT	$L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w} + C_{I,50\text{-}2500}$	$L'_{n,w}$ (1)	$L'_{n,w}$	$L'_{n,w}$	N/A	Class C
IT*	$L'_{n,w}$	$L'_{n,w}$	$L'_{n,w}$	$L'_{n,w}$	N/A	N/A	None (BC ~ Class III)
DE** (2)	$L'_{nT,w}$	$L'_{nT,w}$	$L'_{nT,w}$	N/A	N/A	N/A	None (BC <Class I)
AT (3)	$L'_{nT,w}$, $L'_{nT,w} + C_I$ and $L'_{nT,w} + C_{I,50\text{-}2500}$	$L'_{nT,w}$ and $L'_{nT,w} + C_I$	$L'_{nT,w}$	$L'_{nT,w}$	$L'_{nT,w}$	N/A	None (BC = Class C)
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 (BC ~ Class III)
ISO/WI (5)	$L'_{nT,w} + C_{I,50\text{-}2500}$	$L'_{nT,w} + C_{I,50\text{-}2500}$	$L'_{nT,w} + C_{I,50\text{-}2500}$	$L'_{nT,w} + C_{I,50\text{-}2500}$	$L'_{nT,w} + C_{I,50\text{-}2500}$	$L'_{nT,w} + C_{I,50\text{-}2500}$	N/A

* Classes I, II, III, IV; ** Classes III, II, I; *** Classes I, II, III, IV, V
(1) For references to the standards describing the classification schemes, see Table 1.
(2) The classification scheme has separate criteria for multi-storey and row housing, the latter being 5 dB stricter.
(3) For row housing, Class C has a special 5 dB stricter criterion to match the building regulations; the class is denoted C_R
(4) Use of $C_{I,50\text{-}2500}$ is recommended also in Class C.
(5) The descriptors indicated are those from the ISO/WI 19488. The frequency range is currently discussed.

3 Acoustic quality class ranges and comparison with regulations

In Figures 2 and 3 are found graphical comparisons of lowest and best classes for the classification schemes [4-13]. The regulatory requirements in the same countries have been added. Data are from [4-14] and [1] updated. More information is found in the same references. The most striking differences between countries and between classes are found in impact sound criteria, e.g. the best class in [10] corresponds exactly to the lowest class in [11] and [12], cf. Figure 3. It should be noticed that the ranges in ISO/WI 19488 [14-15] does not include all national classification ranges, especially not for impact sound.

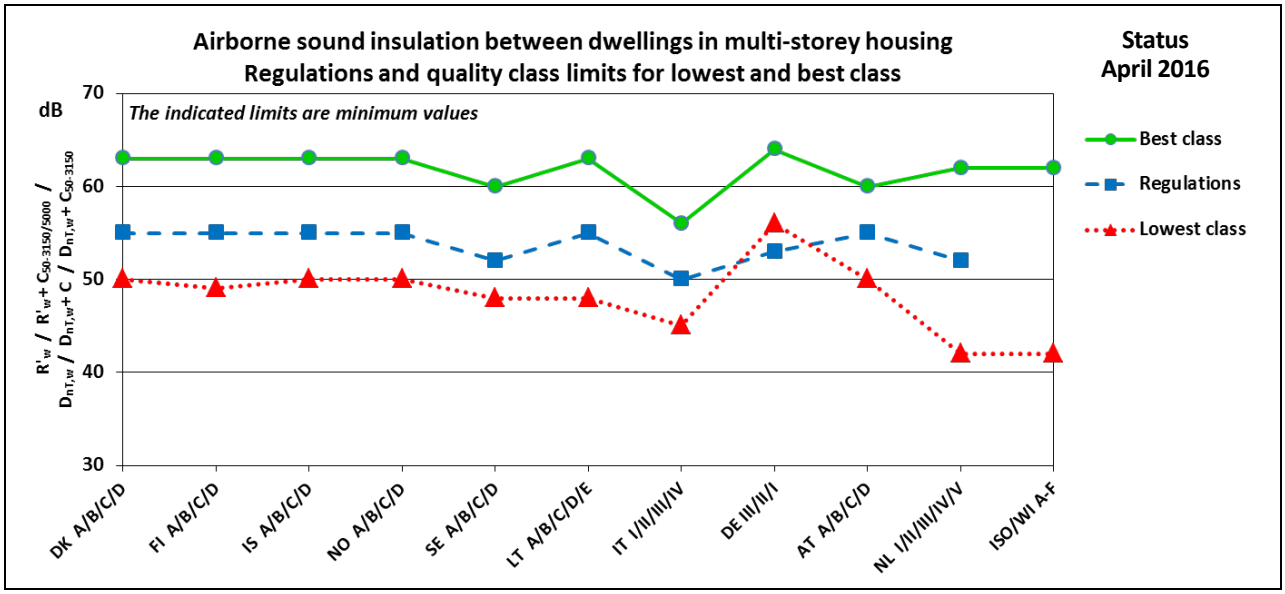

Figure 2: Airborne sound insulation limits for highest and lowest classes in 10 classification schemes in Europe and regulatory requirements for the same countries. ISO/WI 19488 class limits [14] shown in the right side for comparison.
Note: The diversity of descriptors appears from the Y-axis label. The graphs present the numbers only. No conversions between descriptors applied.

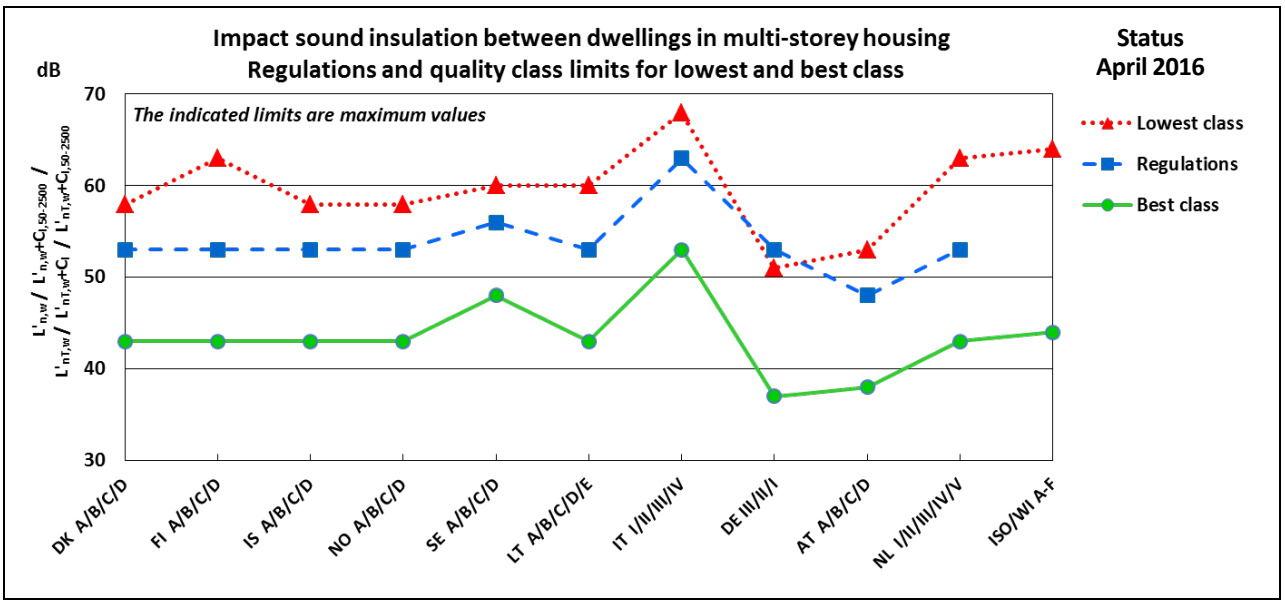

Figure 3: Impact sound insulation limits for highest and lowest classes in 10 classification schemes in Europe and regulatory requirements for the same countries. ISO/WI 19488 class limits [14] shown in the right side for comparison.
Note: The diversity of descriptors appears from the Y-axis label. The graphs present the numbers only. No conversions between descriptors applied.

4 The European housing stock and population

A potential, adverse influence on health is the main reason for having minimum airborne and impact sound insulation requirements in many countries, but the requirements are typically valid for new housing. However, a big part of the housing stock in Europe has been built before implementation of building regulations, and with a sound insulation typically much lower than for new housing. In addition, improvements of sound insulation are seemingly seldom included in housing renovation, e.g. due to lack of knowledge, focus, policies and regulations.

When considering promoting sound insulation improvements in renovation projects, the basis for discussion and development of tools is information about the existing housing stock, the current national requirements for new housing as well as the systems, decision processes and practices applied for renovation of existing housing. As neighbour noise is a bigger problem in flats than in other types of housing, highest priority should be given to multi-storey housing.

The population in EU-28 is over 500 million inhabitants, and there are above 200 million dwellings according to Eurostat or other sources. A profile of the housing stock in Europe is found in [20] and country descriptions in [21]. Eurostat has published census data about population and housing; see e.g. [22-25]. The below Figure 4 shows distribution of dwelling types for the individual countries in EU28+, sorted according to decreasing % of flats in the countries. In 2014, 4 out of every 10 persons in the EU-28 lived in flats; see [22] or Figure 4.

The year of construction is important to identify construction types and evaluate sound insulation, especially from before regulations existed. As construction practice varies across Europe, this should be done on a national basis.

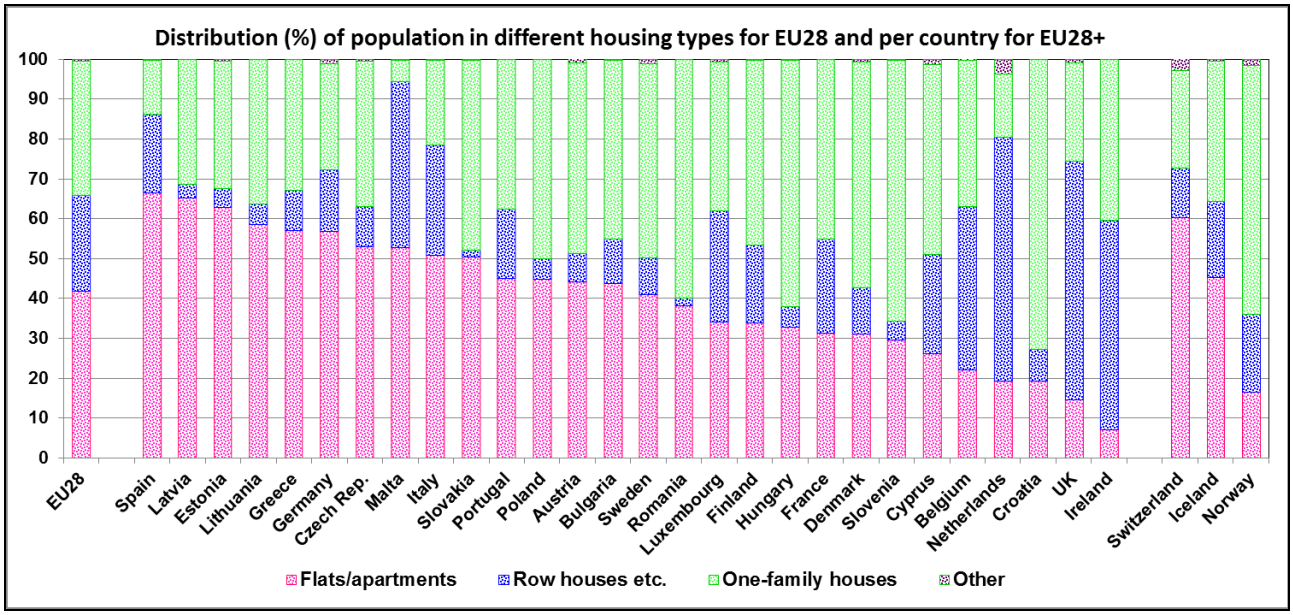

Figure 4: Distribution (%) of population in different housing types for EU28 and per country for EU28+. Data source: Eurostat, data for 2014 (2015 not yet available).

5 Applicability of acoustic classification schemes in the housing stock

It is obvious that acoustic classification could be relevant for existing housing before renovation using lower classes suitable for old housing, if available. From Tables 1-3 it is seen that the five Nordic countries and Italy have one quality class below regulations, Lithuania, Austria and the Netherlands have two classes. Germany (VDI4100) has 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 not in general include acoustic classes fitting major parts of the existing housing stock. In [26], which includes mapping of the Danish housing stock, i.e. number of dwellings according to construction year, constructions and estimated sound insulation, it is suggested to extend the present DS 490 [4] with two lower classes E and F suitable for older housing.

Another important topic is how building regulations deal with sound insulation, when renovating housing. Here, more aspects are relevant, as both the actual contents of the regulations and how it is dealt with by the builders and building

industry and enforced by the authorities are important issues. A small, simple survey was made by looking into the regulations in selected countries, in some cases by asking acoustic colleagues. Concerning policies for renovating or retrofitting, the most clear rules exist for change of use of a building (or parts of it), where requirements are the same as for new-build, e.g. when offices are converted to flats. Other general findings are that it is not (for the same use) allowed to degrade the sound insulation, and new partitions should fulfil current regulations, although these rules are not necessarily clear from the regulation text and enforcement unknown. In some countries the rules are linked to whether a building permit is needed, and if so the current rules for new-build must be complied with. In general, technical possibilities are taken into account, and cultural heritage must be preserved. An initiative from Spain about preparing an "Existing Building Evaluation Report" [27] – before retrofitting old housing for public funds – is interesting and might be considered, when updating procedures in other countries. Although the aim may already exist in most procedures, the detailing about acoustics and related guidelines in the building code seems worthwhile studying. This is one way to make the acoustic conditions visible. Another way is to apply acoustic classes as explained above.

The same principle could be applied for other building categories. Several existing acoustic classification schemes (about half) also include classification of other types of premises, e.g. schools, kindergarten, offices, hotels and healthcare facilities, see examples in Table 4. In the last column of the table is shown the number of pages in the classification schemes, and the variation indicates clearly different philosophies concerning structures and contents.

Table 4: Simplified overview of building categories in existing acoustic classification schemes

Country	Classification scheme (CS)		Dwel-lings	Schools	Kinder-garten	Healthcare facilities	Offices	Restau-rants	Other	No. of pages
DK	DS 490:2007	[4]	+	–	–	–	–	–	–	12 pp
FI	SFS 5907:2004	[5]	+	+	+	+	+	–	+	34 pp
IS	IST 45:2016	[6]	+	+	+	+	+	+	+	45 pp
NO	NS 8175:2012	[7]	+	+	+	+	+	+	+	60 pp
SE	SS 25267:2015	[8]	+	–	–	–	–	–	–	32 pp
	SS 25268:2007	[28]	–	+	+	+	+	+	+	39 pp
LT	STR 2.01.07:2003	[9]	+	+	+	+	+	–	+	18 pp
IT	UNI 11367:2010	[10]	+	+	+	+	+	–	+	100 pp
DE	VDI 4100:2012	[11]	+	–	–	–	–	–	–	33 pp
AT	ÖNORM B 8115-5:2012	[12]	+	–	–	–	–	–	–	20 pp
NL	NEN 1070:1999	[13]	+	–	–	–	–	–	–	22 pp
ISO/WI	ISO/WI 19488	[14]	+	–	–	–	–	–	–	??

Note: The table is simplified and subject to errors due to insufficient language skills and different ways of categorizing buildings.

6 Discussion, conclusions and perspectives

Most European countries have regulatory requirements for sound insulation between dwellings in multi-storey housing, mainly intended and applied for new housing and thus in many countries not describing rules for housing renovation. However, more than half of the European housing stock was built before acoustic regulations were implemented, and due to extensive renovation of the housing stock in most countries and the seemingly very limited attention to upgrading of sound insulation, tools for promoting sound insulation improvement have been identified, hoping that joint efforts could lead to more focus on the issue and the recommended tools could prove useful.

In general, the present national acoustic classification schemes for housing do not have acoustic classes suitable for old housing. Considering the ongoing and expected extensive renovation of housing all over Europe, much more attention to improvement of sound insulation between dwellings should be promoted, as it now appears to be a non-topic in spite of the importance to occupants of dwellings, evaluated from the prevalence of neighbour noise annoyance in several surveys, see e.g. results for Denmark in [29] with 33 % of occupants in multi-storey housing disturbed by neighbour noise and 16 % by traffic noise. Some main findings from German studies and references are included in [29].

Based on findings described, the following tools and initiatives could be recommended aiming at promoting and facilitating upgrading of sound insulation in multi-storey housing, when renovating:

- Review regulations for new-build – to avoid acoustic slum in the future and establish a goal for all housing.
- Assessment of acoustic performance should be a part of the building evaluation before renovation.
- Revise acoustic classification schemes to include lower classes appropriate for existing dwellings (like for energy labelling).
- Prepare a national catalogue of typical housing constructions and related sound insulation.
- Describe retrofitting cases in "Good Practice" publications.
- Revise building regulations to include more clear requirements or recommendations for improving sound insulation, when renovating housing.
- Information to builders, contractors and authorities about construction solutions and importance of sound insulation.
- Construction solutions to be developed further – innovation needed.
- Building authorities might pay more attention to the sound insulation issue and enforcement.

One of the first steps should be to make the acoustic conditions more visible by introducing a "label" or an alternative system that together with other incentives could lead to improvement of sound insulation. However, it is important to emphasize that the initiatives listed above can be launched in parallel. The goal is that upgrading of sound insulation is considered on equal terms with improvement of other qualities, when renovating housing.

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