Acoustic classification of buildings in Europe – Main characteristics of national schemes for housing, schools, hospitals and office buildings

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Summary
Building regulations specify minimum requirements, and more than ten countries in Europe have published national acoustic classification schemes with quality classes, the main purpose being to introduce easy specification of stricter acoustic criteria than defined in regulations. The very first classification schemes were published in the mid 1990'es and for dwellings only. Since then, more countries have introduced such schemes, some including also other building categories like e.g. schools, hospitals and office buildings, and the first countries have made updates more times. Acoustic classification schemes define limit values for a number of acoustic performance areas, typically airborne and impact sound insulation, service equipment noise, traffic noise and reverberation time, i.e. the same as in regulations.
Comparative studies of the national acoustic classification schemes in Europe show main characteristics varying significantly across Europe, e.g. about building types included, number and range of quality classes, acoustic descriptors and limit values, class denotations and relation to building regulations. The classification schemes have developed over time, and limit values have in general - like regulations - become stricter, extended to more building uses and more acoustic performance areas.
The paper summarizes main characteristics of the current national quality classes for housing, schools, hospitals and office buildings. The majority of schemes focus on quality classes corresponding to regulations or higher and have none or few classes below current national regulations, implying that major parts of existing buildings cannot be classified. Among other things, it is concluded that lower classes should be added, thus enabling acoustic classification of existing buildings - like for energy labelling – and make visible the acoustic quality, hoping that improvement of acoustic conditions could be promoted. In general, more collaboration between countries is recommended, implying exchange of experience and potentially leading to improved classification schemes and acoustic quality of buildings.

PACS no. 43.55.Rg, 43.50.Ba

1. Introduction

Building acoustic requirements, classification criteria or other acoustic criteria are found in building regulations, various guidelines with mandatory or voluntary limits, acoustic classification schemes and even in indoor climate standards and in "Green Building" certification rules. The present paper deals with housing, schools, hospitals and office buildings and focuses on acoustic classification criteria, although a brief introduction to acoustic regulations is given, since they are or should be a reference concerning limit values.
In this paper, classification schemes are limited to those having minimum three acoustic classes.

Figure 1. Acoustic classification schemes in Europe, examples of front pages of national documents published by standardization organizations or other organizations.

2. Building acoustic performance areas in regulations

In most countries in Europe, acoustic regulations now exist for housing and schools and in several countries also for other building categories like e.g. hospitals and office buildings. Regulations are typically for new-build only.

Acoustic regulations for housing specify minimum requirements aiming at protecting health for "normal" people with "normal" neighbours. For schools and other educational institutions, the main reasons are to optimize learning conditions for students and working conditions teachers as well as supporting well-being of all people during the variety of situations in such buildings. For hospitals, the main purpose of acoustic limit values is to provide good acoustic conditions for the patients under treatment and for the personnel for the various tasks and activities taking place in the many different kinds of rooms in such buildings. Examples are bedrooms, examination and treatment rooms, corridors, stairwells, waiting and reception areas, dining areas, offices, all with different acoustic needs. For office buildings, the purpose of acoustic limit values is similarly to ensure satisfactory working conditions in the many different rooms in such buildings. Examples of room types are offices, meeting rooms, open-plan offices, corridors, stairwells, reception areas, dining areas.

Acoustic regulations (and classification criteria) are typically about:

- Airborne sound insulation between rooms
- Impact sound insulation between rooms
- Facade sound insulation
- Reverberation time or sound absorption
- Service equipment noise

Building acoustic criteria are specified by a descriptor, a limit value, reference to a standard and sometimes to specific conditions, e.g. frequency range and/or test conditions. In Europe, most countries refer to EN ISO field measurement and rating standards, typically [1-5]. At the design stage, the acoustic performance can be estimated using prediction methods (e.g. [6-7] or other tools) and the relevant acoustic product data.

Since housing has been considered most important, acoustic regulations for housing have existed in many countries since the 1950'es (or even earlier), while regulations for schools and other building categories were implemented later Thus, we know most about housing, and a major part of the descriptions in the following is about dwellings in multi-storey housing. Comparative studies of sound insulation requirements for new housing are found in e.g. [8-9] for 24 countries, and an update of descriptors and limit values for requirements is found in [10] for 35 countries. The comparison between countries shows considerable differences in terms of descriptors, frequency range and level of requirements, cf. [8-10]. For several countries, more information about regulations and housing constructions is found in [11].

Sound insulation descriptors are defined in EN ISO 717 [2], which unfortunately allows a high variety of descriptors. Efforts are made to promote harmonization of descriptors in Europe, see [10]. Various other, less extensive, comparisons for housing and schools have been made, including traffic noise, service equipment noise and reverberation time, see [12-18], and findings show again a high diversity of acoustic descriptors and limit values.

Regulations are most often for new-build only, although some countries have regulations or recommendations for renovated buildings. If acoustic regulations did not exist or were not enforced or were too weak during building design or construction, there is a high risk of insufficient acoustic performance, which is seemingly the case for a major part of the European building stock, although the situation varies considerably across Europe.

3. Acoustic classification in Europe - Overview

Complying with regulatory requirements does not guarantee satisfactory conditions for the users, and since the mid 1990'es, several countries have developed and introduced schemes with acoustic quality classes reflecting different levels of acoustical comfort/protection, the main purpose being to make it easier for developers to specify and for users to require a standardized acoustic quality better than the quality defined by regulations. Thus, lower classes for old buildings are often missing.

In Table I is found a simplified overview of building categories in acoustic classification schemes in Europe. National schemes including housing are found in [19-30], and the international proposal ISO/WI 19488 in [31] with background information in [32]. Other references are [33-35] as indicated in Table I. In Table II is found detailed information about building categories in Norway, Iceland and Turkey, which all have building regulations referring to Class C as the mandatory regulations. Unique is also that all building categories seemingly are included, implying that limit values in these countries are found in just one document.

Table I. Simplified overview of building categories in existing acoustic classification schemes in Europe.

Building categories in acoustic classification schemes in Europe − Status March 2018										
Country	Classification scheme (CS)		Dwellings	Schools	Kindergarten	Healthcare facilities	Offices	Restaurants	Other	No. of pages
DK	DS 490:2007	[19]	+							12 pp
FI	SFS 5907:2004	[20]	+	+	+	+	+		+	34 pp
IS	IST 45:2016	[21]	+	+	+	+	+	+	+	45 pp
NO	NS 8175:2012	[22]	+	+	+	+	+	+	+	60 pp
SE	SS 25267:2015	[23]	+							32 pp
	SS 25268:2007	[33]		+	+	+	+	+	+	39 pp
LT	STR 2.01.07:2003	[24]	+	+	+	+	(+)		+	18 pp
IT	UNI 11367:2010	[25]	+	+	+	+	+		+	100 pp
DE	VDI 4100:2012	[26]	+							33 pp
	DEGA 103:2018	[27]	+							35 pp
	VDI 2569:2016 Draft	[34]					+			33 pp
AT	ÖNORM B 8115-5:2012	[28]	+							20 pp
NL	NEN 1070:1999	[29]	+							22 pp
FR	NF S31-080:2006	[35]					+			18 pp
TR	Regulation on Protection of Buildings against Noise (2017)	[30]	+	+	+	+	+	+	+	Online ~40 pp
ISO/WI	ISO/DIS 19488	[31]	+							21pp

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

Table II. Building categories in three countries (NO, IS, TR) with a wide range of buildings included in acoustic classification schemes and with reference to Class C as the acoustic regulations for all new buildings.

Building/room types in acoustic classification schemes in Norway, Iceland, Turkey − March 2018		
Norway: NS 8175:2012(E) [22]	**Iceland: IST 45:2016** [21], [36]	**Turkey:** [30], [37]
5. General matters on building types and limit values 6. Dwellings 7. Schools and other buildings for teaching purposes 8. Kindergartens and day-care facilities for schoolchildren 9. Healthcare buildings 10. Overnight accommodation 11. Offices 12. Restaurant premises 13. Manufacturing and commercial premises and laboratory buildings 14. Receptions, inquiry desks, foyers, waiting areas, entrances etc. 15. Communication routes 16. Transport, communications and telecommunications buildings 17. Cultural and research buildings 18. Outdoor areas and access routes	6. Dwellings 7. Day-care institutions, kindergartens, primary schools and music schools (for children up to about 16 years) 8. Secondary schools, colleges, music schools etc. (students > 16 years) 9. Hospitals and nursing institutions etc. 10. Hotels etc. 11. Offices 12. Restaurants 13. Premises for production and commerce and research buildings. 14. Receptions, waiting areas, entrance areas etc. 15. Corridors and other areas of communication in buildings. 16. Centrals for public transport. 17. Cultural buildings and sports buildings. 18. Other workplaces, not covered by previous chapters in the standard (sound absorption)	• Residential Buildings • Educational Buildings • Health Services and Rehabilitation Centres • Offices and Administrative Buildings • Hotels • Student dormitory buildings • Cultural Buildings • Commercial Facilities • Terminals • Religious facilities • Entertainment Facilities and Sports Centres • Industrial plants

4. Acoustic classification of housing

An overview of existing national acoustic classification schemes in Europe for housing, [19-30], is found in Table III. For each scheme listed, the class denotations, number of classes and the relation to the national building code are indicated. Table III also includes number of classes below the national regulations, in most cases none or one. Results of comparisons between the national schemes are found in [10, 12, 15, 17, 18]. The sound insulation descriptors (not necessarily the same as in regulations) are found in [18]. Information about the international proposal (ISO/WI 19488) is found in [31-32].

In Table IV, the meaning of acoustic classes is illustrated by indicating different number of classes, denotations and ranges, see also findings below the table. In [26-27] are found more detailed, verbal descriptive indications of perception of various neighbour noises for different acoustic classes.

Table III. European schemes for acoustic classification of dwellings, [19-30], relation to building codes and information about number of classes. ISO/DIS 19488 (2017), [31], has been included for comparison.

Acoustic classification of dwellings - Schemes in Europe and relation to building codes – Status March 2018							
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
DK	2001/2007	DS 490 (2007)	A / B / C / D	+	Class C	4	1
FI	2004	SFS 5907 (2004)	A / B / C / D	–	N/A (BR ~ Class C)	4	1
IS	2003/2011/2016	IST 45 (2016)	A / B / C / D	+	Class C	4	1
NO	1997/2005/2008/2012	NS 8175 (2012)	A / B / C / D	+	Class C	4	1
SE	1996/1998/2004/2015	SS 25267 (2015)	A / B / C / D	–	N/A (See note(4))	4	1
LT	2003	STR 2.01.07 (2003)	A / B / C / D / E	+	Class C	5	2+npd
IT	2010	UNI 11367 (2010)	I / II / III / IV	–	N/A (BR ~ Class III	4	1
DE	1994/2007/2012	VDI 4100 (2012)(2)	III / II / I	–	N/A (BR ~ Class I(2))	3	~ 0
DEGA	2009/2018	DEGA Empfehlung 103 (2018)(3)	A*/ A / B / C / D / E / (F)	–	N/A (BR ~ Class D(3))	6+npd	1+npd
AT	2012	ÖNORM B 8115-5 (2012)	A / B / C / D / (E)	–	N/A (BR = Class C)	4+npd	1+npd
NL	1999	NEN 1070 (1999)	I / II / III / IV / V	–	N/A (BR ~ Class III)	5	2
TR	2017	Noise Protection and sound insulation in Buildings(6)	A / B / C / D / E / F	+	Class C	6	3
ISO/WI	ISO/WI 19488 since 2014	ISO/DIS 19488 (Sept. 2017)	A / B / C / D / E / F and npd	N/A	N/A (See note(5))	6+npd	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.

(2) 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.

(3) 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.

(4) SS 25267 (2015) does not include class C criteria, but refers to values in the BR as class C.

(5) Original proposal prepared by COST TU0901 in 2013. ISO/WI 19488 from 2014, ISO/DIS in Sept. 2017.

(6) "Regulation on Protection of Buildings against Noise" www.resmigazete.gov.tr/eskiler/2017/05/20170531-7.htm (May 2017).

Table IV: Meaning of acoustic quality classes using various, partly fictive ranges and denotations.

High acoustic protection and comfort ☺	**Acoustic quality class**						☹ **Very low acoustic protection and comfort**
	A	**B**	**C**	**D**	**E**	**F**	
	III	**II**	**I**				
			a	**b**	**c**	**d**	
	A	**B**	**C**	**D**			

Comparing the acoustic classification schemes for housing, see Table III and the before-mentioned references, several differences are found, e.g.:

- 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 717:2013.
- Intervals between classes.
- Range of quality classes (~ 8-22 dB for airborne, ~ 14-30 dB for impact) and position.
- Relation to regulatory requirements.
- Sound insulation internally in dwellings.
- Reverberation time in stairwells.
- Procedure for verification of compliance with a specific class.

Thus, acoustic classification schemes are very national and the meaning of an acoustic class not easily understood in other countries. Efforts were and are made to promote harmonization, see [31, 32], and in this way increase learning across borders.

In five countries, see Table III, building regulations refer to a specific acoustic class as the acoustic regulations for housing. An advantage of this is also that attention is drawn to the possibility of choosing a better acoustic quality than minimum as defined by the regulations.

Especially relevant could be lower acoustic classes enabling mandatory acoustic quality marking of existing dwellings before renovation or for information for prospective users/buyers – similar to the mandatory energy labelling according to EPBD [38].

However, most classification schemes do not have acoustic classes fitting old buildings, so to enable acoustic classification for such buildings, lower classes must be implemented.

5. Acoustic classification of schools, hospitals and office buildings

The overview of acoustic classification schemes (ACS) in Table I and the related references show:

- 12 countries have ACS.
- 11 countries have ACS for housing.
- 7 countries (FI, IS, NO, SE, LT, IT, TR) have ACS with schools included. The four Nordic countries (FI, IS, NO, SE) have extensive acoustic criteria. For the other three countries, it is less clear due to reference to separate documents and/or language difficulties.
- 7 countries (FI, IS, NO, SE, LT, IT, TR) have ACS with hospitals included. The four Nordic countries (FI, IS, NO, SE) have extensive acoustic criteria. For the other three countries, it is less clear due to reference to separate documents and/or language difficulties.
- 7 countries (FI, IS, NO, SE, LT, IT, TR) have ACS with offices included in the schemes with several building categories. The four Nordic countries (FI, IS, NO, SE) have extensive acoustic criteria. For the other three countries, it is less clear due to reference to separate documents and/or language difficulties.
- Further 2 countries (DE and FR) have separate documents with classes for office buildings only.

Additional comments on individual countries related to schools, hospitals and office buildings are found below. References are found in Tables I and II.

Denmark
No classification for schools, hospitals and office buildings.

Finland
Schools: Classes A/B, C and D = npd.
Hospitals: Classes A/B, C and D = npd.
Offices: Classes A, B, C, D. For several performance areas, D = C, but not for impact sound and reverberation time.

Iceland
Schools: Classes A, B, C, D.
Hospitals: Classes A, B, C, D.
Offices: Classes A, B, C, D.

Norway
Schools: Classes A, B, C, D.
Hospitals: Classes A, B, C, D.
Offices: Classes A, B, C, D.

Sweden
Schools: Classes A, B, C, D.
Hospitals: Classes A, B, C, D (D often = npd).
Offices: Classes A, B, C, D (D often = npd).

Lithuania
Schools: Classes B, C, D; E.
Hospitals: Classes B, C, D; E.
Offices: In [24], there are some recommended minimum values for offices included as well as references to other documents. Concerning classification, it is indicated that classes for educational premises (i.e. schools) may be applied.

Italy
Schools: Classes I, II, III, IV.
Hospitals: Classes I, II, III, IV.
Offices: Classes I, II, III, IV.

Germany
No classification for schools and hospitals.
For various rooms in office buildings, the draft guideline [34] define three acoustic classes A, B, C (A being the upper class).

Austria
No classification for schools, hospitals and office buildings.

Netherlands
No classification for schools, hospitals and office buildings.

France
No classification for schools and hospitals.
For various rooms in office buildings, [35] define three acoustic performance levels “Standard”, “Efficient” and “Highly efficient”, where “Standard” is indicated as corresponding to regulations, which however do not seem to exist in France for offices.

Turkey
Schools: Classes A, B, C, D, E, F.
Hospitals: A, B, C, D, E, F.
Offices: A, B, C, D, E, F.
The description of regulations and classes are available in Turkish only and not studied further, although it could be interesting, because it’s the latest of all the classification schemes, it includes all building categories and have more classes than the other schemes.

General comments
As for housing, various acoustic characteristics are applied for schools, hospitals and office buildings, and international cooperation could be recommended, aiming at optimizing acoustic criteria for various building and room types.

6. Discussion and suggestions

The main characteristics of acoustic classification schemes in Europe have been summarized, see previous sections. Results from several comparative studies of acoustic requirements and/or classification have been made, see [8-10] and [12-18]. In most of these studies, it is found that levels of requirements and classification criteria as well as descriptors vary considerably between countries.

An important topic is also the whole structure of a building code and related documents. In many countries, it is very difficult to get a complete overview of acoustic regulations, guidelines and recommendations due to a complex variety of documents published by authorities, institutes, councils, standardization organizations and various other organizations and with no joint document linking those documents together.

For many countries, it could be recommended to simplify considerably having – as e.g. in Norway, cf. [22] and [39] – the acoustic part of the building regulations referring to a specific acoustic class in a classification scheme, which includes all building applications, thus being the starting point for the acoustic design criteria of any building.

In Noise in Europe, [40], outdoor noise pollution is identified as a growing environmental concern, which is caused by various sources and is widely present not only in the busiest urban environments, but across the countries. Due to adverse effects of noise, EU prepared the Environmental Noise Directive (END 2002/49), [41], requiring EU member states to assess exposure to noise from key transport and industrial sources and make noise mapping and action plans every 5 years, and extensive efforts are done to make vehicles, roads etc. quieter.

However, according to [42-43], 508 million European citizens spend about 90% of their time indoors, 2/3 of this time in their homes and 1/3 in workplaces, schools, and public spaces. Therefore, Europe‘s buildings have a major impact on Europeans‘ health, but similar attention on a national or European level was not given to indoor noise, although some national neighbour noise surveys indicate that in some countries more people are annoyed by neighbour noise than by traffic noise, cf. e.g. [44] with 33% of individuals in multi-storey housing annoyed by neighbour noise compared to 16% by traffic noise. Adverse implications of neighbour noise on home life seem to be the same as for traffic noise, i.e. sleep disturbances, use of rooms, quiet activities (reading, writing, resting), having a conversation, listening to music/radio/TV, cf. e.g. [45].

On the EU level, the noise policy relates to environmental noise [41]. EU does not have a policy on noise in buildings, e.g. neighbour noise is not included in the EU Noise Policy. Concerning national noise policies, they relate typically to the EU policy and thus in general to environmental noise only. A wider noise policy – worth to copy – is found for England, where the government (DEFRA) has prepared the Noise Policy Statement for England (NPSE), [46], which also includes neighbour noise. Noise policies including noise in buildings seem to be missing in other countries, but could definitely be worthwhile discussing and implementing at both a European level and in the individual countries.

In spite of many people being annoyed by noise in buildings, objective information about the acoustic conditions for buildings is not mandatory and rarely available. In contrast, quality labelling has in general become more widespread - compulsorily or voluntarily. For buildings, Energy Performance Certificates (EPCs) are mandatory whenever a property is built, sold or rented, cf. [38].

Another issue is the trend that acoustic classification criteria appear also in other types of standards and schemes, among these indoor climate standards and green building certification. These schemes have been developed in committees with focus on characteristics other than acoustics, e.g. indoor climate and/or energy, and the criteria and denotations are often not consistent with those of the acoustic regulations or classification schemes.

It would be advantageous, if a harmonized acoustic classification scheme could be developed based on experience from national schemes, and acoustic classes for indoor climate and green building certification could then refer to such classes instead of developing new classes.

In practice, the application of acoustic quality labelling for buildings seems to be limited for various reasons, one of them being that acoustics is a ‘hidden’ quality, you do not ‘see’, before you live in it. However, the strongest resistance seem to come from those, who own buildings and dwellings, and are afraid of losing money, if the acoustic quality became visible through an announced acoustic class. The following quote from [47] indicates the potential benefit of mandatory acoustic labelling:

> *“There is no doubt that a mandatory classification of dwellings would create a mechanism of continuous improvement of acoustic quality of buildings under the pressure of buyers’ demands”* (about [25])

To avoid acoustic slum in the future and support the process for acoustic renovation and acoustic upgrading in general, the following initiatives are suggested:

- Introduce acoustic regulations for refurbished buildings, starting with housing.
- Extension of acoustic classification schemes to include classes for old buildings.
- Mandatory acoustic labelling of new buildings and of existing premises, when sold or rented out (as for energy labelling).
- Preparation of acoustic classification schemes with all/several building categories included.
- Develop noise policies to include noise in buildings – at a European as well as national level.

Based on findings for housing, schools, hospitals and office buildings, there is a high potential for cooperation in Europe, aiming at improving acoustic quality by learning from each other, introduce the needed regulations and policies and not least practice enforcement.

Acknowledgements

The author is grateful to the acoustic colleagues, who assisted by answering questions about the national acoustic regulations, classification schemes in their country. However, the author is solely responsible for errors in the paper, and any comments, corrections and updated information will be appreciated.

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