A Comparison Between National Scheme for the Acoustic Classification of Dwellings in Europe and in the U.S.

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The classification of dwellings according to different building performances has been proposed through many schemes worldwide in recent years. The general idea behind these schemes relates to the positive impact a higher label, and thus a better performance, should have. In particular, focusing on sound insulation performance, national schemes for sound classification of dwellings have been developed in several European countries. These schemes define acoustic classes according to different levels of sound insulation. Due to the lack of coordination among countries, a significant diversity in terms of descriptors, number of classes, and class intervals occurred between national schemes. However, a proposal "acoustic classification scheme for dwellings" has been developed recently in the European COST Action TU0901 with 32 member countries. This proposal has been accepted as an ISO work item. This paper compares sound classification schemes in Europe with the current situation in the United States. Economic evaluations related to the technological choices necessary to achieve different sound classification classes are also discussed. The hope is that a common sound classification scheme may facilitate exchanging experiences about constructions fulfilling different classes, reducing trade barriers, and finally increasing the sound insulation of dwellings.

1. INTRODUCTION

Recent research has proven how sound insulation deeply correlates with productivity, higher learning outcomes, and concentration.[1–3] However, beyond annoyance or decreased productivity, poor acoustical environments also affect health. The World Health Organization has repeatedly linked the population's exposure to environmental noise with adverse health effects and has established a relationship between traffic noise and an increased risk of cardiovascular diseases.[4,5] At the same time, an emerging body of research has linked the exposure to environmental noise with sleep disturbance, cognitive impairment in children, and Tinnitus, among other human health concerns.[4,6] All of these studies show that the indoor acoustic performance deeply matters for the quality of the built environment.

The majority of countries in Europe have a long tradition of regulatory sound insulation requirements for dwellings, going back to the 1950s in some cases.[7,8] The purpose of these regulations is the protection of health. However, the fulfilment of these requirements does not ensure satisfactory conditions, and the protection is typically insufficient for sensitive persons or in the case of loud neighbours. For this reason, classification schemes have been introduced in several countries to specify higher levels of acoustical comfort. The first classification schemes for dwellings were implemented in the early 1990s.[8] A scheme generally defines a number of classes according to a certain interval of some acoustic indicators that are used to reflect different levels of acoustic comfort.

Findings from comparative studies of regulatory sound insulation requirements and sound classification schemes in Europe show that sound insulation descriptors, regulatory requirements, and classification schemes have a high degree of diversity.[9–11] These studies have concluded that harmonization is needed to facilitate the exchange of data and experience among countries and to reduce trade barriers.

This paper considers that sound insulation requirements are a national issue that cannot be made homogenous worldwide. However, the comparison of the ongoing experience towards a harmonized European classification scheme with the situation in the U.S. would help building stakeholders to familiarize with acoustic classes fitting local needs and conditions.

2. CLASSIFICATION SCHEMES IN EUROPE

2.1. Existing Sound Classification Schemes in Europe

A sound classification scheme could be defined as a set of a minimum of three classes with different sound insulation performance levels. Using this definition, classification schemes for dwellings exist, at present, in ten countries in Europe.[8] Sound classification schemes indicate different quality classes to meet different needs of activities and quietness.[10] They have generally been developed as technical standards, but sometimes they are already referred to in national laws.

Acoustic class information could be considered as an analogy to energy labelling or other labelling systems. In fact, any acoustic classification scheme allows specifying acoustic conditions in a way that is similar to other qualities.

Sound classification systems in Europe are national schemes, the majority of which have been published by national standard organizations.[11] An overview of existing sound classification schemes for dwellings is reported in Table 1. For each scheme, information is found about class denotations, relation to the national building code, and classes intended for new and for existing (old, renovated, and other not new) housing, respectively. The schemes specify class criteria concerning several acoustic aspects. These are described in more detail in recent publications for party walls and floors between dwellings[8] and for facades.[10, 12]

An international standard or technical specification would help improving awareness, knowledge and communication about the quality of acoustic conditions and hopefully improve housing stock. With this idea, a proposal "acoustic classification scheme for dwellings" has been developed recently in the European COST Action TU0901 with 32 member countries,[13] and the proposal has been accepted as an ISO work item.[14] Table 2 reports a preliminary proposal within this ISO work item. Although the work is just started in the ISO working group and changes will certainly occur, based on the COST action results, Table 1 shows a preliminary classification currently discussed. While several of the national classification schemes also include other building types than housing, the proposed ISO scheme is for housing only.

2.2. The COST TU0901 Proposal for a Joint Acoustical Classification Scheme

The main characteristics of the COST TU0901 proposal for an acoustic classification scheme for dwellings are, ISO/NP 1948814:

- It includes class criteria for airborne and impact sound insulation, noise from traffic and other external sources, and noise from service equipment, plus the optional evaluation of the reverberation time;
- It defines six classes (from A to F) with 4 dB steps between classes. For each class, there is a choice between sound insulation criteria down to 50 Hz or the common lower limit of 100 Hz;
- It may be used for describing the acoustic conditions in new as well as in existing housing, before and after renovation;
- It may be used for information to occupants of dwellings, including prospective tenants or buyers;
- It may be considered by the legislators as a basis for a national set of requirements;
- It may be used as reference for sustainability marking or labelling;
- Although descriptors are based on existing ISO standards, ISO 140-4, -5, -7 (now being transferred to ISO 16283, parts 1 to 3) and ISO 717 (2013), a simpler denotation has been used to avoid criteria indicated as a sum.

Comparison of the current sound insulation requirements in most of the European countries show that the requirements fit into class D in Table 2 on average, although with large deviations for service equipment and facades. This shows that the classification scheme includes ratings for dwellings with higher acoustic protection than corresponding to the current minimum ones.

3. SOUND INSULATION REGULATIONS IN THE UNITED STATES

3.1. National and Local Sound Insulation Codes

The situation in the United States (U.S.) is particularly different from that in Europe. US building codes have historically been developed by organizations of building officials, and have then been adopted as law by jurisdictions. At the end of the last century, the three main building code organizations that represented most U.S. jurisdictions (Building Officials and Code Administrators International – BOCA, International Conference of Building Officials – ICBO, and Southern Building Code Congress International - SBCCI) merged to form the International Code Council (ICC). This is a private organization with membership building code officials. The ICC serves updating the International Building Code (IBC) that may be adopted by states, counties, and localities.

Cities and towns publish noise ordinances that appear as part of their regulations or zoning planning by laws. These are usually emission type regulations as they typically control the sound that a source may produce at a receptor location. On the other side, the building code is intended to set a standard to ensure construction quality, by establishing a minimum sound isolation performance of constructions.

The IBC Section 1207, the one dedicated to noise control, includes the airborne and impact sound isolation performance of constructions that separate dwelling units. The airborne sound isolation performance limit is expressed as a minimum party wall and floor/ceiling sound transmission class (STC) rating of 50, if such a rating has been determined based on sound transmission loss measured in a laboratory, or 45 if determined from noise reduction measured in the field.[16] Similarly, the impact sound isolation performance limit is expressed as a minimum floor/ceiling impact isolation class (IIC) rating of 50, if such a rating has been determined on the basis of impact sound pressure levels produced by an ISO tapping machine and measured in a laboratory, or 45 if it has been determined from tapping machine sound pressure levels measured in the field (IBC, 2012).

Tocci described how the IBC has been modified in some local codes, such as the California Code of Regulation and the Building Code of the City of New York.[17] Generally, these local codes include some more prescriptions than the IBC. For examples, the City of New York requires an STC that is higher than 50 if based on laboratory reports or higher than 48 if field-tested, and an IIC higher than 51 if based on laboratory reports but higher than 49 if field-tested. Emission-type aspects such as the maximum sound power levels for mechanical equipment and the day-night average sound pressure emission level are also prescribed in the New York City and California code, respectively.

Table 1. European schemes for the sound classification of dwellings, relation to building codes, and indication of classes intended for new and "old" dwellings. Status June 2013. A new proposal prepared by COST TU0901 and approved as WI within ISO has been included for comparison. Table from Rasmussen and Machimbarrena.[15]

Country	Class denotations(1)	CS Reference (latest version)	Link BC to CS	BC Reference to CS	Comment	Classes for new dwellings	Classes for "old" dwellings
DK	A / B / C / D	DS 490 (2007)	+	Class C		A, B, C	D
FI	A / B / C / D	SFS 5907 (2004)	-	N/A	BC = Class C	A, B, C	D
IS	A / B / C / D	IST 45 (2011)	+	Class C		A, B, C	D
NO	A / B / C / D	NS 8175 (2012)	+	Class C		A, B, C	D
SE	A / B / C / D	SS 25267 (2004)	+	Class C		A, B, C	D
LT	A / B / C / D / E	STR 2.01.07 (2003)	+	Class C		A, B, C	D, E
IT	I / II / III / IV	UNI 11367 (2010)	-	N/A	BC ∼ Class III	I / II / III / IV	
DE(2)	III / II / I	VDI 4100 (2012) (3)	-	N/A		III, II, I	None
AT	A / B / C / D / E	ÖNORM B 8115-5 (2012)	-	N/A	BC = Class C	A, B, C	D, E
NL	I / II / III / IV / V	NEN 1070 (1999) (4)	-	N/A	BC ∼ Class III	I / II / III	IV, V
COST TU0901	**A – F and npd**	**ISO docs[14]**	**N/A**	**N/A**	**(5)**	**A / B / C/D/E/F/ and npd**	

Abbreviations: BC = Building Code (regulatory requirements); CS = Classification scheme
(1) Classes are indicated in descending order, i.e. the best class first.
(2) Moreover, 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 Rw and Ln,w to DnT,w and LnT, 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) The classification scheme (including verbal explanations of classes) is described in (Gerretsen, 2009).[16]
(5) Proposal prepared by COST TU0901 (2013).[14,17] Submitted as Work Item for international standardization, (ISO, 2014).[15]

Table 2. Class criteria for airborne and impact sound insulation as proposed after the COST TU0901. Table from Rasmussen and Machimbarrena.[15]

Type of space	Class A DnT,50 (dB)	Class B DnT,50 (dB)	Class C DnT,50 (dB)	Class D DnT,50 (dB)	Class E DnT,50 (dB)	Class F DnT,50 (dB)
Between a dwelling and premises with noisy activities	≥ 68	≥ 64	≥ 60	≥ 56	≥ 52	≥ 48
Between a dwelling and other dwellings and rooms outside the dwelling	≥ 62	≥ 58	≥ 54	≥ 50	≥ 46	≥ 42

Type of space	Class A LnT,50 (dB)	Class B LnT,50 (dB)	Class C LnT,50 (dB)	Class D LnT,50 (dB)	Class E LnT,50 (dB)	Class F LnT,50 (dB)
In dwellings from premises with noisy activities	≤ 38	≤ 42	≤ 46	≤ 50	≤ 54	≤ 58
In dwellings from other dwellings	≤ 44	≤ 48	≤ 52	≤ 56	≤ 60	≤ 64
In dwellings: from common stairwells and access areas balconies, terraces, bath, toilet not belonging to own dwelling	≤ 48	≤ 52	≤ 56	≤ 60	≤ 64	≤ 70

3.2. How Far Are the United States from a Classification Scheme?

Section 3.1 has shown that the normative situation in the U.S. is far from a classification scheme. The main obstacles for this are that:

- the evaluation in the U.S. is mainly based on making a comparison with listed assemblies according to laboratory test reports often obtained through product manufacturers that have tested their products. Only in some local codes (such as the California Code) a report by an acoustical consultant or a field measurement approach may be required. Moreover, the general approach in case of real measurement is that if the STC or IIC ratings are measured, then the IBC permits lower ratings;

- the voluntary approach of the IBC provokes significant differences between jurisdictions, with some having adopted it, whereas others have passed specific legislations to modify or remove the noise control section;

- the IBC only applies to multifamily dwellings and a lack of prescriptions about other building types exists, including all the non-multifamily residential buildings;

- the criteria are assessed through two single indicators, the STC evaluated above 125 Hz only, and the IIC evaluated above 100 Hz without being able to report low frequencies properties and does not take into account the requirements of the facades.

It can be expected that, at this time, an acoustic classification scheme in the U.S. may only be introduced within the context of sustainability assessment systems for buildings. Over the past several years, the U.S. Green Building Council has endeavoured to migrate the LEED rating system toward a global standard, taking into account various environmental design issues holistically. In fact, in the last few years, the high-performance design community has begun to recognize the importance of acoustical comfort as an important sensory aspect in assessing the indoor environmental quality (IEQ). As part of this recognition, the recent versions of LEED have included some acoustical requirements.[18] As an example, the USGBC first recognized the importance of acoustical comfort within environments for learning and healing, and so LEED for

Schools 2009 and LEED for Healthcare 2009 rating systems featured the following IEQ credits for acoustical performance:

- Schools-2009 EQp3: Minimal Acoustical Performance. Background noise from HVAC must be limited to 45 dB(A), and core learning spaces need a reverberation time below 1.5 seconds;
- Schools-2009 EQc9: Enhanced Acoustical Performance. Project teams are required to limit the background noise to a more challenging 40 dB and to meet ANSI Standard S12.60-2002, except windows, which must have an STC rating of at least 35;
- Healthcare-2009 EQc2: Acoustic Environment. The credit focuses on designing the facility to meet or exceed the sound and vibration criteria outlined in the 2010 Facility Guidelines Institute's Guidelines for Design and Construction of Health Care Facilities and the 2010 Sound & Vibration: Design Guidelines for Health Care Facilities.

In LEED v4, the previous credits have been made more stringent. For example, the prerequisite for schools now specifies a maximum HVAC background noise level of 40 dB(A). A new requirement asks high-noise sites to implement measures to mitigate sound transmission into core learning spaces. With LEED v4, USGBC has also broadened the notion of acoustic performance as an important IEQ issue by introducing a (pilot) credit for exterior noise control and expanding the niche acoustic performance credits into other building types. With the intent of establishing a comprehensive acoustic performance evaluation, USGBC has also proposed a credit in LEED BD+C Homes v4, which deals with "acoustically sensitive" spaces, such as bedrooms and dining rooms. The requirement may be satisfied using a prescriptive compliance path or a performance compliance path; in the first category, requests enforce common IBC prescriptions, by asking that "Attached single family homes and multi-family homes must have party walls with a minimum STC rating of 55. All party wall penetrations must be sealed with acoustical sealant and floor/ceiling assemblies must have a minimum STC and IIC rating of 55". Moreover, this USGBC credit focuses on four aspects:

- HVAC background noise. Mechanical equipment needs to be located strategically to reduce its impact, according to the 2011 ASHRAE Handbook, (Ch.48, Table 1) or AHRI Standard 885-2008 (Table 15). The credit also references to the ASHRAE 2011 Applications Handbook (Table 6) for maximum HVAC noise levels;
- Sound transmission/isolation. Appropriate construction assemblies and design strategies need to mitigate sound movement between spaces;
- Reverberation time. This is based on room type and application and can be affected by space geometry and by the presence and location of sound-absorptive finishes;
- Sound reinforcement and masking systems. These systems help to improve the sound clarity and privacy in an interior.

Another acoustic related credit in the new USGBC systems is in LEED Operations and Maintenance, the "Occupant Comfort Survey". This requires an acoustic evaluation, underlining the importance of subjective perception for the comfort and wellness in a space.

Although the trend in considering more acoustic aspects in sustainability rating systems, the current LEED system seems far from having a structure to characterize different sound insulation classes.

4. DISCUSSION

One of the more controversial aspects in acoustic classification schemes regards the economic implications that may follow the decision to adopt a higher sound insulation class. For example, a few years ago, an acoustic classification scheme was developed as an Italian technical standard UNI 11367 (Table 1).[22] This scheme was never linked to a national law given the controversial effects that it could have had over the construction market.[19] In fact, the general perception of acoustic classification schemes was that the new legislation standard could be very demanding in terms of performance requests and hence expensive in terms of construction over-costs. Studies have shown that this risk is generally overestimated.[20,21] Also, the classification schemes were not intended to become mandatory, but they aimed to define schemes in order to recognize best practices.

An analysis of the construction costs of technological solutions useful in the same building to achieve sound higher insulation classes revealed an increase of around 1% for a basic improvement in the sound insulation class, and around 4% for achieving the highest quality class pointed in the Italian standard UNI 11367.[19] Results of this analysis are reported in Table 3. The building was a concrete based building, with heavy cavity walls with insulation, and double glass windows; these technologies influence the specific cost necessary for achieving better sound insulation levels, and so the results cannot be assumed to be valid for other building systems. Attention should also be paid to the fact that this analysis did not take into account the costs of proper designing focused on obtaining higher sound insulation, and it only assumed that higher sound insulation standards were obtained through more performing building technologies. However, it is known that during the design most of the insulation problems may be solved, often without cost. Proper acoustic design requires not only adequate construction solutions, but also a rationalization of the internal distribution with a reduction in conflicts between functions and a careful analysis and execution during the construction phases.[19]

Another important aspect that the current discussion about acoustic classifications of dwellings has raised is the opportunity to introduce metrics that help the common public understand the meaning of sound insulation indicators and metrics. This aspect seems to be fundamental in order to rise the attention to more stringent sound insulation requests. An interesting preliminary scheme has been proposed by the COST Action TU0901, and it is reported in Table 4.

5. CONCLUSIONS

This paper has presented an overview of existing schemes for the sound classification of dwellings. Systems in place in European countries have briefly been presented to show their

Table 3. Acoustic classification according to the Italian standard UNI 11367 obtained for different building technologies. Table from Berardi.[19]

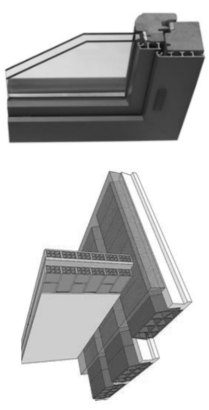
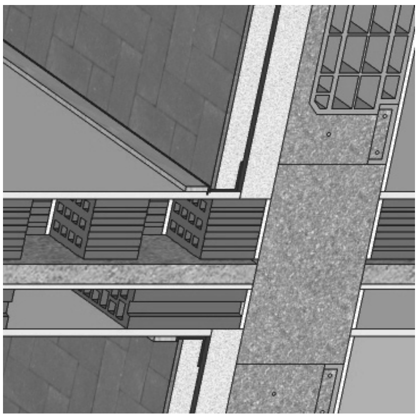
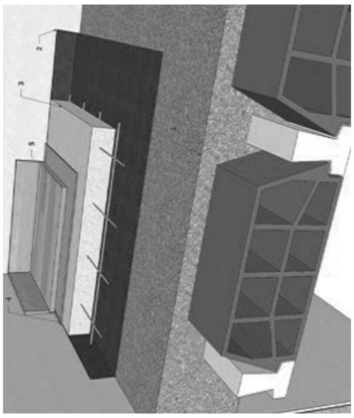
Sound Insulation Class	Facade sound insulation $D_{nT,w}$ [dB]  Double cavity brick wall with 12cm brick facing, rockwool insulation and 10 mm internal plaster. 30% façade is glazed surface.	Airborne sound insulation R'_w [dB]  Heavy cavity brick wall with rockwool insulation and 10 mm plaster on both sides	Impact sound insulation $L'_{n,w}$ [dB]  Floating floor over a concrete beam and ceramic block floor, with 10 mm plastered. Detail of the floating floor:	Incremental cost over the IV sound insulation class
IV	≥ 32	≥ 45	≤ 68	-
	34 Internal wall in hollow bricks 20 cm with 5 cm rockwool with a density of 50 kg / m^3 Double glass 4/6/4	**46** Double wall in hollow bricks (12 + 12 cm) with 5 cm rockwool with a density of 50 kg / m^3	**64** with PE polyolefin resin 5 mm	
III	≥ 37	≥ 50	≤ 63	<1%
	37 Internal wall in hollow bricks 20 cm with 5 cm rockwool with a density of 70 kg / m^3 Double composite glass 8.4/6/5	**51** Double wall in hollow bricks (12 + 8 cm) with 5 cm rockwool with a density of 70 kg / m^3	**62** with double PE polyolefin resin 10 mm	
II	≥ 40	≥ 53	≤ 58	<2%
	41 Internal wall in hollow bricks 20 cm with 7 cm rockwool with a density of 70 kg / m^3 Double composite glass 8/16/6.4	**54** Double wall in hollow bricks (12 + 12 cm) with 7 cm rockwool with a density of 70 kg / m^3	**57** with polyethylene foam and a sheet of lead foil 6 mm	
I	≥ 43	≥ 56	≤ 53	~4%
	43 Internal wall in hollow bricks 20 cm with 10 cm rockwool with a density of 70 kg / m^3 Double composite glass 10/12/8.4	**56** Double wall in hollow bricks (12 + 8 cm) with 10 cm rockwool with a density of 70 kg / m^3	**53** with double polyethylene foam and a sheet of lead foil 12 mm	

Table 4. Examples of the global indication of what can be expected for some airborne and impact sound sources.[15]

Noise source	Class A	Class B	Class C	Class D	Class E	Class F
loud speech	hardly audible	just audible, but not intelligible	audible, but hardly intelligible	just intelligible	intelligible	clearly intelligible
loud music	not audible	just audible	audible	clearly audible	very clearly audible	loud music
dropping & moving objects	not audible	hardly audible	just audible	audible	clearly audible	very clearly audible

structure. Then, the paper has focused on the proposed "acoustic classification scheme for dwellings" recently developed by the European COST Action TU0901. This proposal will be discussed within an ISO working group. The paper has also summarized the current state of sound insulation requirements in the U.S. The comparison reveals that the U.S. are far from considering an acoustic classification scheme. However, the current development of sustainability rating systems and, in particular, the attention that LEED has recently recognized to some acoustic parameter represents an important step in the U.S. market to go beyond the building code requirements. The hope is that sound classification schemes may facilitate exchanging experiences internationally, reducing trade barriers, and increasing the sound insulation of dwellings.

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