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# Acoustic classification of dwellings using national and international standard: a critical comparison

Marco Caniato*, Andrea Gasparella
Faculty of Science and Technology, Free University of Bozen-Bolzano, Bozen, Italy
* corresponding author: mcaniato@unibz.it
Federica Bettarello
AcusticaMente Designers Team, Conegliano, Italy
Chiara Schmid
Department of Engineering and Architecture, University of Trieste, Italy

**Summary**
The international standard organization (ISO) is currently working on a standard project (pr ISO/DIS 19488: 2017 E) describing classes reflecting different levels of acoustical comfort in new housing and a tool for characterizing levels of acoustical conditions in older housing. The Italian standard organization has provided a voluntary standard in 2010 (UNI 11367) and in 2012 (UNI 11444) based on acoustic parameters. Nevertheless, parameters, reference values, measurements methods and classification procedures are different from those in the ISO standard.
This work will illustrate a critical analysis on the two approaches in order to analyze and compare technical and economical enforcement.

## 1. Introduction

National building regulation often describe minimum requirements regarding noise insulation and human protection.
However, even if the acoustic performance of walls, floors and service equipment comply with regulatory requisites, satisfactory conditions are not always guaranteed for occupants, since mandatory requirements are very often minimum levels related to barely sufficient privacy.
For these reasons, standards focused on acoustical indoor comfort are needed in order to classify and sort dwellings both new and existing.
At present, different European countries (Figure 1) have improved and developed documents reporting guidelines for acoustical classification of buildings [1]-[11].
Nevertheless, these methods use very different procedures, tests and calculations in order to assess final classes.
Even materials manufacturers tried to handle this topic with public proposals [12].

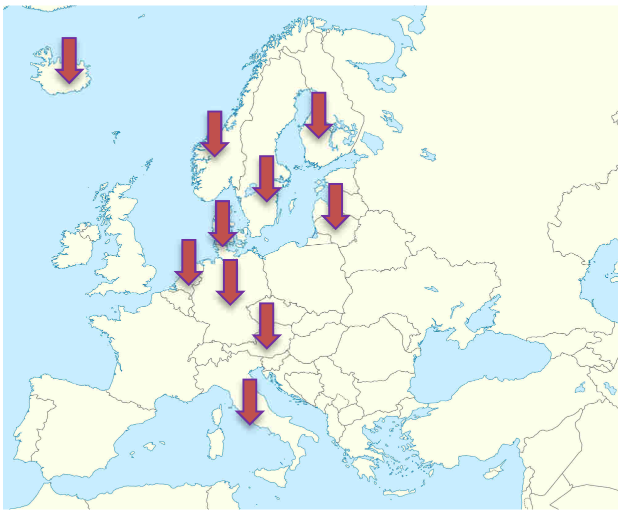

Figure 1 – Geographical distribution

In France, C. Guigou-Carter et al. [13] proposed a method for building classification, likewise Espinel et al. [14], [15] in Spain.
In the U.S. there currently is no proposal for acoustical classification even if LEED protocols include some acoustic parameters as well [16].

This fact causes virtual borders between countries since it is almost impossible to compare performances, exchange experiences, common strategies and procedures [17].
For this purpose, a new ISO standard has been discussed recently [18]. It contains two alternative procedures for acoustical housing classification and it is intended to unify all European methods.
The purpose of this paper is to analyze the content of the ISO standard and to compare it with the Italian ones. A critical dissertation is then provided, highlighting advantages and disadvantages of the two approaches.
The reference at Italian classification is related always to the two complementary standards [7]-[8].

## 2. Materials and methods

In order to compare the two standards a general overview of their composition, structure and contents is reported. Then, a focus on classification method is described and compared assessing pros and cons of both proposed procedures.

### 2.1 Simplified overview

In Table I a summary of the number of pages (excluding index, foreword and introduction), paragraphs (including sub paragraphs), parameters to be taken into account, annexes, indoor comfort, type of housing, compulsory filed measurements and included methods is reported.
At a first sight, it is evident that the Italian standards are much more complex than the ISO one. Number of pages, annexes and paragraphs show a different articulation, content and detail.
The type of housing that could be classified using the two methods represents another big difference. The Italian proposal include many kind of destinations and clearly exclude others like gas station, etc. ISO standard include only residential dwellings.
The International method allows classifying individual room or even a single specific characteristic such as airborne sound insulation or impact noise level, separately, while Italian standard does not.
Both of the standards request field measurements but for the ISO they are not compulsory. Finally, according to the latter one, there are no classifying methods or parameter regarding indoor comfort except for the reverberation time in stairwells and access areas.

Table I. Summary of general descriptors

| Descriptor | ISO standard | UNI standards |
|---|---|---|
| Pages number | 15 | 100 |
| Paragraphs number | 14 | 22 |
| Parameters numbers | 10 | 10 |
| Annexes number | 2 | 10 |
| Dwellings | yes | yes |
| Schools | no | yes |
| Hospitals and similar | no | yes |
| Offices | no | yes |
| Others | no | yes |
| Number of classification methods | 2 | 2 |
| Compulsory field measurements | no | yes |
| Classes number | 6 | 4 |

### 2.2 Parameters analysis

The two methods take into account similar parameters. A summary of them is reported in Table II, sorted by requirement.

Table II. Summary of requested parameters

| | ISO standard | UNI standards |
|---|---|---|
| Airborne sound insulation | $D_{nT,50}$; $D_{nT,A}$ | $D_{nT,w}$; $R'_{w}$ |
| Sound insulation against exterior noise | $D_{nT,A,tr}$ | $D_{2m,nT,w}$ |
| Impact sound level | $L'_{nT,w}$; $L'_{nT,50}$ | $L'_{n,w}$ |
| Noise from building service equipment | $L_{A,eq,nT}$; $L_{AF,max,nT}$ ($L_{AS,max,nT}$ may also be used) | $L_{ic}$ ($L_{A,eq,nT}$); $L_{id}$ ($L_{AS,max,nT}$) |
| Indoor comfort | $T_r$ in access areas | $T_r$, $C_{50}$, STI |

For airborne sound insulation, the main difference is that ISO standard prefers the standardized level difference (eq. (2)) instead of the apparent sound reduction index (eq. (3)). The two terms substantially differ only because in the computation of $R'_w$ the surface value of the partition is taken into account, allowing a better comparison with laboratory measurements.

(1) $D = L_1 - L_2$

(2) $D_{nT} = L_1 - L_2 + 10 \log T/T_0$

(3) $R' = D + 10 \log S/A$

where $L_1$ is the energy-average sound pressure level in the source room, $L_2$ is the energy-average sound pressure level in the receiving room, T is s the reverberation time in the receiving room, $T_0$ is the reference reverberation time; for dwellings, $T_0 = 0{,}5$ s, S is the area of the common partition, in square meters and A s the equivalent absorption area of the receiving room, in square meters [19].
On the other hand, $D_{nT}$ provides a straightforward link to the subjective impression of airborne sound insulation. As a matter of fact, final values do not considerably vary in most cases.
ISO standard requires that $D_{nT}$ is corrected with frequencies terms "C" and "$C_{50\text{-}3150}$" according to ISO 717-1 [20]. The influence of these spectrum adaptation terms is very useful to assess subjective noise perception.
For the façade sound insulation the only difference is that ISO standard require the correction of the $D_{2m,nT,w}$ term with "$C_{tr}$" parameter according to ISO 717-1, for same reasons of airborne sound insulation.
As for the other two parameters, impact noise level in ISO standard is corrected using a spectrum adaptation term $C_{I,50\text{-}2500}$ according to ISO 717-2 [21], while UNI standards refer to the unmodified $L'_{nw}$, implying the same consideration described for the other parameters.
Service equipment classification and verification follow two distinct methodologies. Both of them divide service equipment into continuous ($L_{A,eq,nT}$) and discontinuous ones ($L_{AF,max,nT}$ /$L_{AS,max,nT}$).
The indoor comfort is not evaluated in ISO standard since the reverberation time prescriptions are only related to stairwells and access areas with the only aim to reduce the noise starting from these volumes and possibly propagating inside dwellings. On the other hand, Italian methodology includes schools, hospitals, offices, etc. proposing $T_r$, $C_{50}$ and STI indexes for the classification of indoor comfort, clarity and intelligibility of the speech.

## 2.3 Classes and limits analysis

The ISO standard proposes six classes whether the Italian ones only four.
Limits in UNI standards are provided for every requirement and class; they are permanent and they could not vary because of external noise or type of source.
On the other hand, International method for every requirement changes limits as a function of noise source, class or external noise.
For airborne sound insulation classes A and B take into account $D_{nT,50}$ while for other classes the reference parameter is $D_{nT,A}$. Limits also vary according to the time of noise source or adjoining volume (common stairwells, premises, etc.).
For impact noise, classes A and B take into account limits both for $L'_{nT,w}$ and for $L'_{nT,50}$ at the same time (except for stairwells and balconies), while for classes from C to F only the first parameter is evaluated. In addition, limits are divided using adjoining volumes or noise source.
ISO standard classifies sound insulation against exterior noise basing on $L_{den}$ values. This fact implies the external measure of this parameter (at least 24 hours). The result has to be compared to $D_{nT,A,tr,}$ thus taking in to account spectrum adaptation term.
UNI methodology takes into account the field measurement of $D_{2m,nT,w}$ term and limits do not vary according to external noise.

## 2.4 Verification

Another big difference from ISO and Italian standards are the verification procedures.
For the UNI methodology field measurements are compulsory and are the only method to assign the final class.
For the international document, two alternative methods are possible: field measurements (10% of all partitions) or theoretical evaluations combined with visual inspection during the construction process and, once the building is completed, a selection of 5% of the structure will be measured.
UNI procedure is split into parts. In [7] the procedure for the measurement choice for modular buildings is described in Annex G, where sampling methods are included. In [8], the process for the

other types of constructions is defined. In all cases, field measurements are compulsory and requested.

## 3. Discussion, conclusions and perspectives

It is evident that the two methodologies have few things in common, however both have pros and cons to be contrasted.

### 3.1 ISO standard pros and cons

The **advantages** of ISO standard is the clearness and easiness of use. The method is very short an there is no need of description since measurement procedures (when needed) or theoretical evaluation are left to the person or the organization appointed for these tasks.
The requests are clear and, even if often they vary because of different related parameters, the procedure is easy.
The classification process is cheap, since theoretical analyses may be used instead of expensive field measurements. This is true for all parameters except for façade insulation, since the $L_{den}$ value is requested. Its simulation involve expensive 3D programs and the collection and managing of traffic noise, estimation of the sound power level of different possible sources like industrial plant, anthropic activities and so on.
Another advantage is that the use of the standardized level difference as well as the frequency corrections by means of spectrum adaptation terms express all values related to indoor comfort rather than absolute index such as $R'_w$. The presence of low frequency range up to 50 Hz clearly refers to lightweight timber buildings [22]-[24] where this band range is the most annoying [25]-[27].
Another advantage is the possibility to classify a single parameter, performance or building element.
The disadvantages of the ISO procedure lay mainly in the chance to use theoretical analysis as well as few field measurements (10% / 5%). This could lead to an underestimation or an overestimation of dwellings or whole buildings performance.
As a matter of fact, during visual inspections, the possibility of controlling every single detail is rather low. Monitors could not be in building yard at every time during the day nor every day or week. This would extremely raise costs, thus turning the field measurements as the cheaper way of classification.
Another disadvantage is that theoretical analyses fail to determine objective values since predictive calculation often under or overestimates performance, because there is a lack of theoretical equations in many building acoustic field such as flanking transmissions determination, timber and multilayered structures modelling and so on.
Furthermore, even laboratory measurements provide considerably uncertain values related to low frequencies. Predictive formulas could not be more precise and cannot take into account workmanship. Measurements or calculation uncertainty has to be evaluated case by case.
Furthermore the low frequency noise assessment is very elaborated since long waves are very difficult to measure [29] and rarely the receiving rooms perform as diffuse sound fields.
For this reason, tests have to be executed in corners (Figure 2) and results have to be merged with conventional ones (100 Hz – 3150 Hz range).

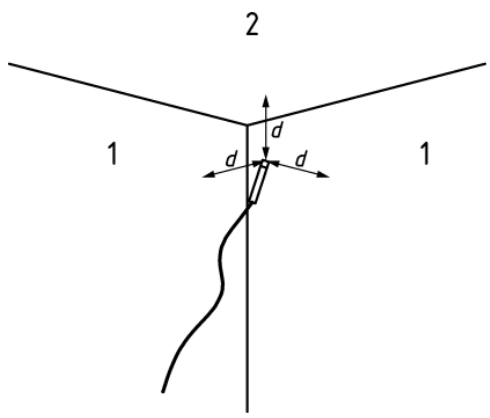


Figure 2 – low frequencies assessment in buildings [19]

### 3.1 UNI standard pros and cons

The **advantages** of using UNI standards are basicly related to the reliabilty, repeatibility and reproducibility of the adopted methods. Since the classification procedure is well described, many cases are included and very few degrees of freedom are left to the person or organization appointed for the measurements. Classes assessment is very robust and there are fewer possibility of disputes.
Furthermore not only residential dwellings are included but many kind of housing are possible targets.

Another advantage is the chance to classify indoor volumes such as classrooms, healthcare facilities, small auditorium, etc. using speech clarity $C_{50}$ and speech intelligibility STI in addition to reverberation time $T_r$.
The uncertainty of measurement is provided by the standard and it is based on the Dutch standard NPR 5092:1999 [28], so there is no need of a complete estimation. In Table III the measurement uncertainty $U_m$ is reported.

Table III. Measurement uncertainty $U_m$ for UNI standard

| | $U_m$ |
|---|---|
| $D_{2m,nT,w}$ (dB) | 1 |
| $R'_w$ (dB) | 1 |
| $L'_{nw}$ (dB) | 1 |
| $L_{ic}$ dB(A)) | 1.1 |
| $L_{id}$ (dB(A)) | 2.4 |

Furthermore if the target building is not modular, a precise list of options and possible choices are described and included, helping the person in charge to choose the right way of sorting partitions and service equipment to test. This will limit uncertanty and rise the robustness and repeatibility of the method.
The main **disadvantage** of the Italian method is classification costs. In fact, in many cases the measurements of requirements related to all structures is easier than perfoming samplig procedure with the related calculations, in order to extend the results to the whole building. As a matter of fact for a block of 20 apartements more than 50 field measurements have to be performed in order to classify single typology of dwellings.
Another disavantage is that sampling method is very complicated and difficult to manage when classifying block with many apartments. This refrain both designers, monitors and constructors to perform acoustic classification since in Italy it is voluntary.
Furthermore, only four classes are present and this may exclude older buildings with lower perfomance.
Based on the findings described, a bulleted list may be drown and proposals could be put forward:

- Existing and future tools for the acoustic certification of buildings are failing in reaching a general public, and creating social awarness, since the requirements are too specialized. As a matter of fact, if certification processes are too complex or expensive, neither designers, nor monitors or final users will show interest in them.
- If national regulations do not take into account classes and refer to specific standar as mandatory requisites, the certification will remain voluntary and won't be able to innovate building market. For this reason, there is a need to introduce lower classes in order to include older or low performance building; thus general public could notice the possible differences.
- Field measurements have to be the only way of certification but cannot be confined to just 5% of the whole partitions or serve equipment since theoretical analyses and visual inspecitons won't substitute *in situ* test.
- The need of precise guidelines focused on how to choose right partitions and service equipement to test is of paramount importance. This will gaurantee robustness, reapitibility and riproducibility.
- A common European labeling or alternative system have to be adopted for a collective awarness on building perfomance
- Education of constructors, desingers and monitors will be very useful and it will facilitate the dissemmination of acoustic coulture and indoors comfort.

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## Author Contributions

Marco Caniato and Federica Bettarello developed the research. Marco Caniato defined the methods and comparisons. Marco Caniato and Federica Bettarello described potential future developments. Chiara Schmid and Andrea Gasparella overviewed and supervised the research. Marco Caniato wrote the paper.

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