The Italian classification scheme of buildings – application to apartments and schools

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ABSTRACT

The Italian acoustic classification of buildings is described by two standards, now under revision. The UNI 11367 gives a detailed description of the classification scheme, including sampling procedures and calculation of uncertainty and is useful for buildings with a large number of homogenous elements. The UNI 11444 involves the selection of the "worst case" in a sample of measurable building elements in order to identify the building units to be completely measured. Both standards are based on voluntary application, except for the specific case of public buildings, for which there are some enforced requirements. In fact, in the case of new construction, renovation and maintenance of public buildings, environmental criteria must be pursued (CAM Decree 2017), including building acoustics (class II and other requirements of UNI 11367) and indoor acoustic comfort criteria (UNI 11532). For the latter, the standard gives limit values for the descriptors, although, for the moment, only the limit values for schools are published. This paper describes the classification procedures and reports case studies of apartments and schools in Italy where the procedure and the limit values are applied.

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1. INTRODUCTION

Procedures for the acoustic classification of buildings have been published in several countries but a methodology for the correct implementation and verification of acoustic requirements in new and existing buildings has been defined only in very few cases. Appropriate criteria to obtain reliable results in term of classes with a reduced number of measurements seems to be the most difficult challenge. The proposal of the international standard ISO/DTS 19488 [1] on the acoustic classification of dwellings describes two alternative verification procedures; one is based on calculations, visual inspections and field measurements, while the other is based only on field measurements. In this second case, at least a sufficiently representative 10% of all types of construction of separating walls and floors must be measured.

In Italy, there are two correlated voluntary national standards on acoustic classification. UNI 11367 gives a detailed description of the classification scheme, including sampling procedures and calculation of sampling uncertainty and is useful for buildings with many homogenous elements. UNI 11444 describe the procedure to identify the "worst case", using minimum performance criteria, to identify the building units to be completely measured.

The Italian classification scheme arises not only from the need to describe different levels of acoustic comfort in dwellings, but also to clarify some aspects of acoustic measurements in building that have caused a number of different interpretations, application problems and disputes on the application of the requirements. The problem of the acoustic protection of residential buildings has been present in Italy since the 1950s in various national and regional regulations and recommendations for social housing constructions and other types of buildings [2]. In 2010, when the standard UNI 11367 [3] on acoustic classification of buildings was published, a new legislative decree was awaited and a draft was shared between the Ministry and the sector associations, but after that, the legislative process did not continue. In the last 10 years, starting with what is considered the beginning of the crisis in the construction sector, there has been an opposite trend, moving towards less sensitivity and attention to the subject of building acoustics.

2. THE ITALIAN ACOUTIC CLASSIFICATION PROCEDURES

2.1. The procedure given by UNI 11367

The Italian standard UNI 11367-2010 (under revision) [3] describes the procedures to define the acoustic classification of single properties. The classification can be expressed for each requirement or as a single descriptor. The requirements considered are listed below:

- single-number quantity of façade sound insulation $D_{2m,nT,W}$;
- single-number quantity of airborne sound insulation of internal partition R'_W;
- single-number quantity of impact sound insulation $L'_{n,W}$;
- sound pressure level from service equipments divided into those with continuous and discontinuous operation (L_{ic} and L_{id}).

Table 1 shows the limit values referred to the different acoustic quality classes of buildings with residential, office, accommodation (hotels, pensions and similar), recreational, cult and commercial destinations. For schools and hospitals, the classification scheme is not applied but optimal values, divided into base and superior, are given by the standard.

The determination of the acoustic classes is based on the average values of the performance of all the in-situ measurements carried out on the various elements. The classification can be based on the measurements of all the measurable elements or of a number of elements through a sampling procedure; in the latter case the sampling uncertainty needs to be applied. The description of the calculation is reported in [3, 4, 5]. Regarding the sampling procedures [6]. of UNI 11367, applicable to buildings with repeated elements (called from now serial buildings), these involve the identification of homogeneous groups for each requirement, in terms of element type and dimensions, test rooms dimensions and installation techniques. Specific indications for the definition of the homogenous groups are listed below; a homogeneous group is defined when the identity is verified on the following aspects:

- façade sound insulation: window/door type and configuration, total façade surface, volume and dimensions of the receiving room, windows/doors surface and dimensions, etc;
- airborne sound insulation of internal partitions (walls and slabs): partition surface and dimension, volume and dimensions of the receiving room, type of partitions (materials, mass, etc), boundary conditions, etc;
- impact sound insulation: floor type plus same parameters described above;
- noise from service equipment: equipment type and features, operating conditions, system distribution of the equipment inside the building, volume and dimensions of the receiving rooms, etc.

Regarding the elements and room dimensions, a 20% tolerance is allowed. For every homogeneous group at least 10% of elements (with a minimum of 3 elements) are identified to carry out measurements. In the case of residential buildings, homogeneous groups should be composed of elements belonging to different dwellings. Within each homogeneous group, the arithmetic mean of each requirement and the corresponding sampling uncertainty is calculated.

The sampling uncertainty is related to the sampling standard deviation s_{sh} and the coverage factor k which depends on the chosen confidence level and on the number of measurements.

The “representative value” of the performance of each homogeneous group is obtained by subtracting (for insulations) or adding (for impact and equipment noise) the unilateral uncertainty to the averaged value. Then, for each dwelling, each technical element belonging to a homogeneous group must be associated to the related representative value and the energetic mean, for each requirement, must be calculated between different homogeneous groups.

The application of the sampling procedure for serial buildings, with a large number of very similar elements (such as hotels or large residential areas with repeated buildings), could strongly reduce the number of measurements. For non-serial buildings, with many building units whose elements do not repeat so often, the sampling procedure does not sufficiently limit the number of measurements. This is the case of the majority of residential buildings in Italy, with a small number of homogeneous technical elements and thus a high number of homogenous groups with a consequently high number of measurements.

Table 1: Limit values referring to the different acoustic classes of buildings according to UNI 11367.

Acoustic class	$D_{2m,nT,W}$ (dB)	R'_W (dB)	L'_{nW} (dB)	L_{ic} (dBA)	L_{id} (dBA)
I	≥ 43	≥ 56	≤ 53	≤ 25	≤ 30
II	≥ 40	≥ 53	≤ 58	≤ 28	≤ 33
III	≥ 37	≥ 50	≤ 63	≤ 32	≤ 37
IV	≥ 32	≥ 45	≤ 68	≤ 37	≤ 42

2.2. The procedure provided by UNI 11444

The UNI 11444-2012 (under revision) [7] is a national standard which concerns the acoustic classification of building units. It contains the guidelines for the selection of building units in non-serial buildings and refers, with simplifications, to the classification procedure given by UNI 11367. In figure 1 it is synthetically described the process to decide which is the most convenient procedure to be used.

This standard describes the procedure to select the “worst case” in a sample of building units based on the most critical measurable building elements, according to specific criteria (minimum performance criteria) given for each requirement. The units that must be selected are those with more critical conditions (lower acoustic performances expected) with reference to the different requirements to be measured. A minimum percentage of 10% of building units (or dwellings) must be selected (with at least 2, for buildings with no more than 4 units, and 3, for buildings with up to 30 units). In each selected building unit, the requirements of all internal partitions and façades and of all the service equipment must be measured according to the procedure given by UNI 11367.

It must be noted that the final acoustic classification of the building will be referred only to the building units that have been measured, while for the other units it is under the responsibility of the construction company to extend the results of the acoustic classification.

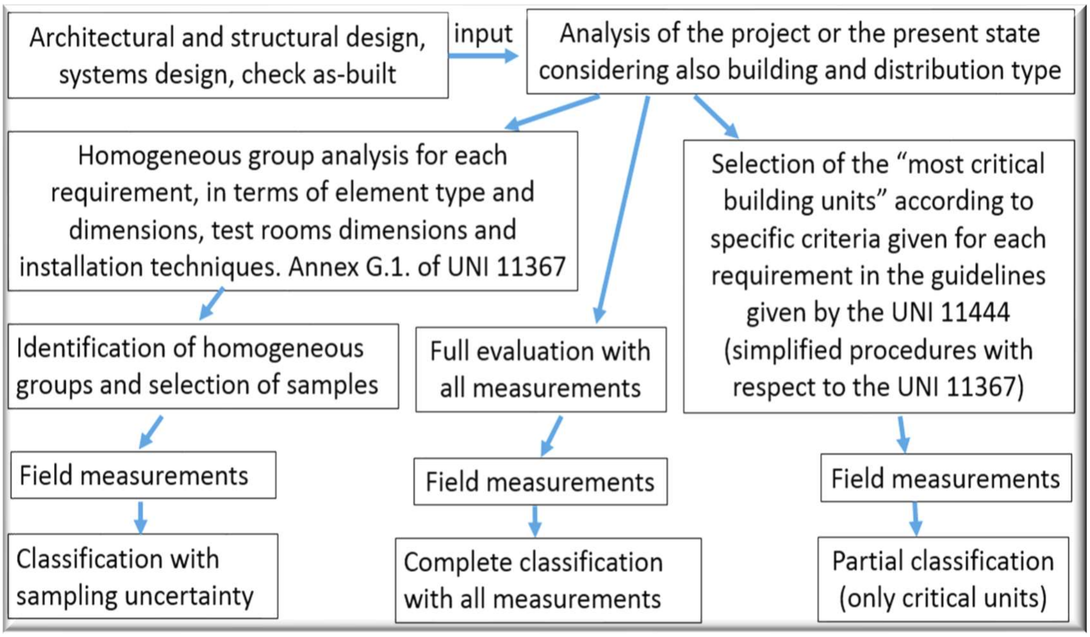

Figure 1: layout with the decision-making process for the most convenient procedure.

2.3. Consideration on the revision of the UNI 11367 and UNI 11444 standards

In the ten years following its publication, the Italian acoustic classification scheme has been applied only in a few cases. The reason is mainly due to the fact that the procedure is considered quite laborious and therefore expensive, in a critical period of the construction sector. With the standard UNI 11367, the reduction of the number of measurements requires the application of the sampling procedure and the sampling uncertainty, which is theoretically correct but complicated from a practical viewpoint. The sampling uncertainty is a function of the difference between the measurements and the confidence level chosen for the evaluations. By applying a high level of confidence and in the presence of some measures that provide different results (this is easily verifiable), the sampling uncertainty can lead to very significant corrections. The standard suggests the possibility of choosing between three levels of confidence (70, 75 and 80%) and this produces results which are not entirely comprehensible for many people. Furthermore, normally there is a small number of homogeneous technical elements and this determines a large number of homogeneous groups within each requirement, with a considerable number of measurements and calculations of the sampling uncertainty.

Therefore, one of the purposes of the revision of UNI 11367 is to provide the necessary bibliographic and regulatory updates, and fully integrate the UNI 11444 standard into the revised UNI 11367 by adopting its method for the selection of the elements to be evaluated.

The current procedure of UNI 11367 is in fact numerically compatible with the transition to a classification based on minimum performance criteria.

The revised UNI 11367 will also include useful guidelines for its application to even partial renovation and refurbishment. Finally, an Annex will be added with indications on calculation methods to be applied to estimate classes at the design stage.

3. THE ITALIAN ACOUSTIC REQUIREMENTS FOR PUBLIC BUILDINGS

3.1. The Ministerial Decree 11 January 2017 "New buildings, renovation and maintenance of public buildings"

The most recent legislation is the Ministerial Decree (DM) of 11-1-2017 (decree on Minimum Environmental Criteria, updated in 11 October 2017) [8] for public buildings, which makes reference to the UNI 11367 for the acoustic classification standard and to the UNI 11532 [9, 10] for the requirements of indoor environments. Since the DM has recently been issued, there are still not enough experiences to understand if this procedure could also work for private buildings, with appropriate adaptations of requirements and procedures. According to the DM, in the case of new construction, renovation and maintenance of public buildings, environmental sustainability criteria must be pursued. Specifically, the values of the building acoustic requirements of public buildings must comply with class II of the UNI 11367 standard (table 1). Furthermore, hospitals and schools must meet the level of "superior performance" shown in table A.1 of standard 11367 (table 2). Specific requirements are also introduced for partitions to communal areas, an aspect neglected by current legislation but very important for acoustic comfort. In this case the reference values are those characterized as "good performance" in table B.1 of the UNI 11367 standard (table 3).

The interior environments of public buildings must also comply with the limit values defined by UNI 11532 as regards the reverberation time, T, the speech transmission index, STI, and the clarity, C_{50}.

The designer must demonstrate compliance with the limits both in the design phase (acoustic project) and in the final verification of the compliance by means of on-site measurements.

Table 2: Limit values for *hospitals and schools, referring to the level of "superior performance" according to table A.1 of the UNI 11367.*

Descriptor	Annex A – UNI 11367
Façade sound insulation	$D_{2m,nT,w} \geq 43$
Airborne sound insulation between the room and other properties (building units)	$R'_w \geq 56$
Normalised Impact Sound Insulation between different building unit	$L'_{nw} \leq 53$
Corrected equivalent sound pressure level from service equipment with continuous operation (different room from the source)	$L_{ic} \leq 28$
Corrected maximum sound pressure level from service equipment with discontinuous operation (different room from the source)	$L_{id} \leq 34$
Airborne sound insulation between two rooms or between a room and other rooms (horizontal partition)	$D_{nT,w} \geq 55$
Airborne sound insulation between two rooms or between a room and other rooms (vertical partition without doors)	$D_{nT,w} \geq 50$
Normalised Impact Sound Insulation for the same building unit	$L'_{nw} \leq 53$

Table 3: Limit values for public buildings, referring to the level of "good performance" according to table B.1 of the UNI 11367.

Descriptor	**Annex B - UNI 11367**	
	Hospitals and schools	**Other use**
Airborne sound insulation between a room and a communal area (vertical partition with doors)	$D_{nT,w}$ ≥ 30 (dB)	$D_{nT,w}$ ≥ 36 (dB)

3.2. The standard UNI 11532 and its proposal of improvement

The UNI 11532 is a national standard, published in 2018, which concerns the acoustic performances of indoor environments and is mandatory for new and refurbished public buildings where good speech perception is required (schools, offices, hospitals and other). The part 1 of the UNI 11532 describes the relevant quantities and their calculation procedure for the control of the acoustic quality of indoor environments. The main acoustic descriptor defined by UNI 11532 are: the reverberation time, T, the speech transmission index, STI, and the clarity index, C_{50}. Part 2 of the UNI 11532 [10, 11] deals with acoustic requirements of indoor spaces of schools and has been recently published, with the indication of the optimal values referred to the above-mentioned descriptors. For the other sectors, the optimal values of the descriptors will be defined in the different parts of the standard that will be published in the coming months and years.

Limit values for reverberation time given by UNI 11532-2 must be verified in the condition of occupied indoor spaces. This condition can be obtained, at the design stage, by means of reference values of sound absorption area of people given by an annex to the standard. The optimal values of the reverberation time are reported in table 4.

Table 4: Optimal values of the reverberation time for the different school activities.

Type of space	**Opt. value of T (s) (with 80% of occupation**	**Volume of the room (m^3)**
Music	$T_{opt.} = 0.45 \lg(V) + 0.07$	$30 \leq V < 1000$
Speech – conferences	$T_{opt.} = 0.37 \lg(V) - 0.14$	$50 \leq V < 5000$
Speech – conferences with interaction teacher - student	$T_{opt.} = 0.32 \lg(V) - 0.17$	$30 \leq V < 5000$
Lessons, including special needs	$T_{opt.} = 0.26 \lg(V) - 0.14$	$30 \leq V < 500$

The reference values for the descriptor STI (speech transmission index), are the following: STI ≥ 0.55 with SPL = 60 (dBA) at 1 (m) in front of the sound source, with a volume smaller than 250 m^3; STI ≥ 0.5 with SPL = 70 (dBA) at 1 (m) in front of the sound source, with a volume larger than 250 m^3; the values are considered without sound amplification system, for furnished rooms with maximum two people.

The verification of the STI according to UNI 11532-2 requires, at the design stage, the estimation of the noise emitted by the equipment and of the background noise in the indoor environment. This aspect could make the verification rather complex. Furthermore, in field verifications, the measurement uncertainty must be considered for all descriptors used.

According to UNI 11532-2, in indoor environments with a volume smaller than 250 m^3, the clarity C_{50} can be verified instead of STI. The reference value for the descriptor C_{50}, considered for a furnished room with maximum two people, is $C_{50} \geq 2\ (dB)$. The value is considered $without\ sound\ amplification\ system$ and is obtained from the average of the results obtained for the octave bands of 500, 1,000 and 2,000 Hz.

4. CASE STUDIES

4.1. Case study 1: residential building with 24 flats

The case study refers to the acoustic classification of a building considering a number of measurements progressively larger starting from the elements with the expected lower values, using the minimum performance criteria given by UNI 11444. The case study is a small tower building, composed of 24 flats. In the test case, the minimum number of measured partitions considered for the classification was approximately 20 % of the global number of measurable elements for façades and impact sound of floors, and 30 % of the different partitions in the case of Sound Reduction Index of internal vertical partitions. In this case study we did not consider the Sound Reduction Index of floors and the equipment noise.

The first step was the identification, for each requirement, of all the measurable technical elements of the entire building system and the subsequent arrangement of the same according to the critical order. The objective was to verify that the progressive increase in the technical elements considered, chosen starting from the most critical, resulted in a progressive improvement in the determination of the results and of the acoustic class for each requirement.

The following tables (tables 5, 6, 7) show the results of this calculation, indicating the scale from lower to higher expected performance, the number of technical elements measured, the energy averaged index relating to each group, the respective range of results, the progressive average index and the progressive acoustic class (calculated by gradually adding the results obtained with the previous groups).

Table 5: Results of the measurements for the façade sound insulation index, ordered from the lower to the higher expected performance and correspondent acoustic class (UNI 11367).

From lower to higher expected performance	Number of elements	Average $D_{2m,nT,w}$ for each group [dB]	$D_{2m,nT,w}$ progressive results [dB]	Progressive acoustic class (UNI 11367)
1 – Façade with a French-door with three panes	4	35.1	35.1	IV
2 – Façade with 2 French-doors with two panes	18	39.0	38.0	III
3 – Façade with a French-door with two panes without balcony	19	36.9	37.4	III
4 – Façade with a French-door with two panes with balcony	11	36.4	37.2	III

Table 6: Results of the measurements for the airborne sound reduction index of vertical partitions, ordered from the lower to the higher expected performance and correspondent acoustic class (UNI 11367).

From lower to higher expected performance	Number of elements	Average R'_w For each group [dB]	R'_w Progressive results [dB]	Progressive acoustic class (UNI 11367)
1- Double masonry wall with small interspace	4	49.2	49.2	IV
2- Double masonry wall with larger interspace with passage of piping	6	53.8	51.3	III
3- Double masonry wall with larger interspace without piping	6	55.3	52.4	III

Table 7: Results of the measurements for the impact sound level index, ordered from the lower to the higher expected performance and correspondent acoustic class (UNI 11367).

From lower to higher expected performance	Number of elements	Average $L_{n,w}$ For each group [dB]	$L_{n,w}$ Progressive results [dB]	Progressive acoustic class (UNI 11367)
1 – ceramic flooring	4	66.1	66.1	IV
2 – parquet flooring with 2 French-doors on the source room	14	55.8	60.8	II
3 – parquet flooring with 1 French-door on the source room which is irregularly shaped	6	54.2	59.8	II
4 – parquet flooring with 1 French-door on the source room which is regularly shaped	10	54.5	58.8	II

The analysis of this case study shows that the progressively precautionary criterion, starting from the minimum expected performance, for the selection of the samples is verified particularly for the impact sound level but also for the airborne sound insulation. The application to the façade sound insulation strongly depends on the regulation of the frames: only if all the windows of a building system are regulated in an accurate way, is it probable that the order of criticality has actually been verified. This case study has been presented in a more complete way in [6].

4.2. Case study 2: measurements in several schools before and after refurbishment

In recent years, a research concerning the acoustic conditions of schools in Italy involved different kinds of schools (mainly primary and nursery schools) located in different Italian Regions (mainly in Lombardy and Tuscany) [12].

Reverberation time measurements were carried out in a sample of 89 classrooms while facade sound insulation in 95 classrooms (mainly the same of the reverberation time). In the latter case, measurements were made before and after the refurbishment works carried out to improve the sound insulation of facades. The average volume of the sample of classrooms was 170 m^3.

Regarding the reverberation time, considering that the measurements were made before the publication of the UNI 11532-2, which require occupied condition, the comparison was made with the following optimal values, T_{opt}, given in in annex C of the UNI 11367, in indoor spaces used for speech (schools and others), in which V is the volume of the space (m^3):

$$RT_{opt} = 0.32\lg(V) + 0.03\ (s)\ \ (for\ indoor\ spaces\ used\ for\ speech)\ (500 \div 1{,}000\ \text{Hz})$$

Furthermore, in indoor unoccupied spaces, the reverberation time must fulfill the following limit between the octave bands of 250 and 4,000 Hz:

$$T \leq 1.2\, T_{opt}\ (s)(250 \div 4{,}000\ Hz)$$

Figure 2 shows the average reverberation time in this sample of classrooms with error bars given by +- the standard deviation, with the optimal and the limit values (dotted lines) given by UNI 11367.

Figure 3 shows the percentage distribution of classrooms with the ratio between the average measured value (250 ÷ 4,000 Hz) and the limit value of reverberation time. Only 34% of this case study of classrooms fulfil the limit of UNI 11367.

Figure 4 shows the rating of the facade sound insulation before and after the refurbishment works. It can be noted that before these works no classrooms fulfilled the limit values given by UNI 11367 ($D_{2m,nT,W} \geq 43$ dB).

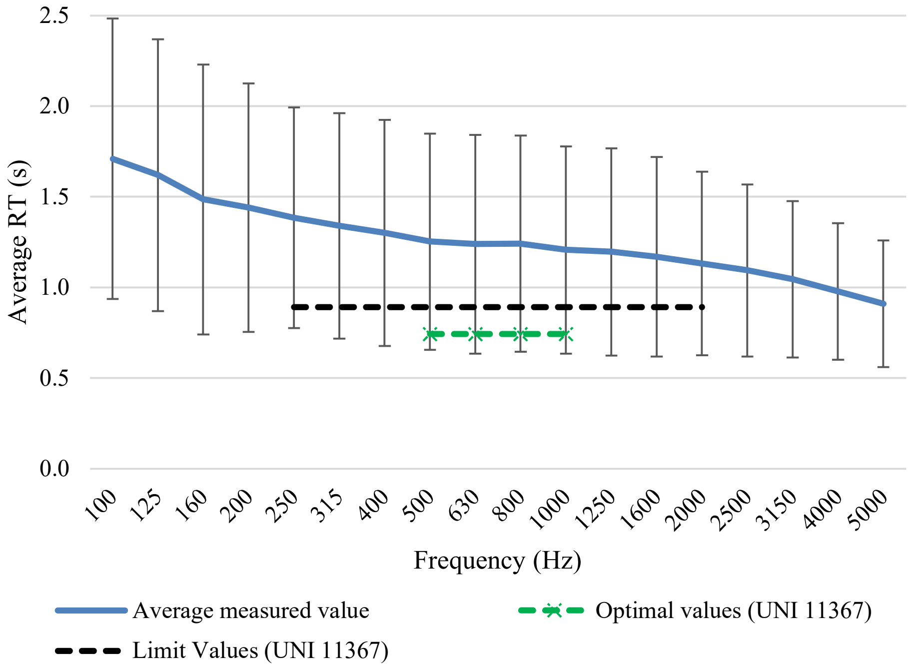

Figure 2 - average value of reverberation time in 89 Italian classrooms with error bars given by +- the standard deviation, with the reference value given by the upper limit of UNI 11367 referred to the average value of the volume of the classrooms

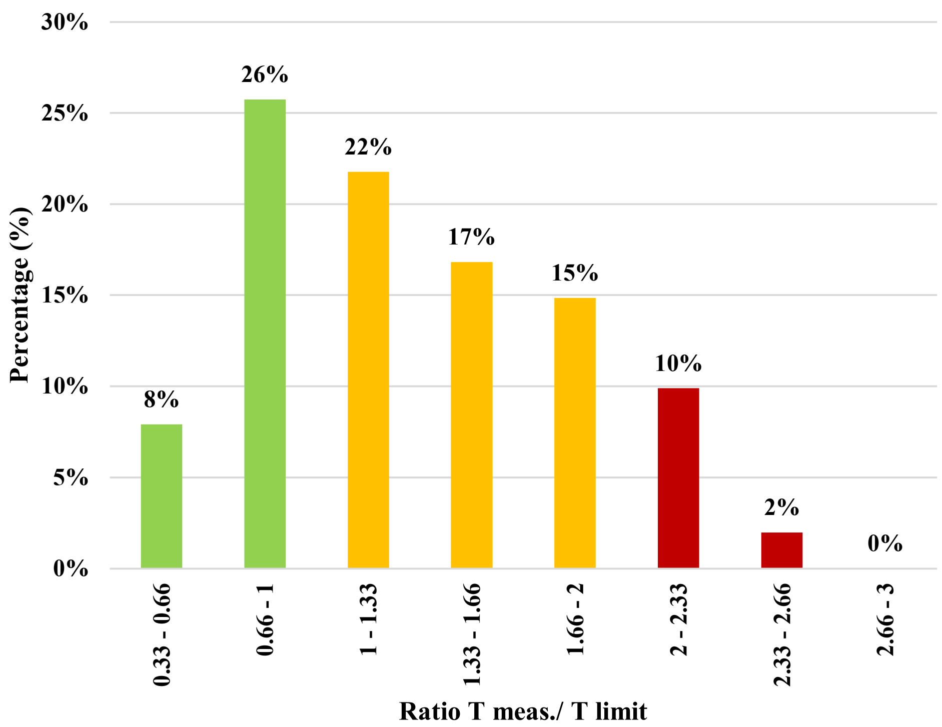

Figure 3 - Percentage distribution of classrooms with respect to the ratio between the measured value of T and the limit value given by UNI 11367 referred to the volume of each classroom.

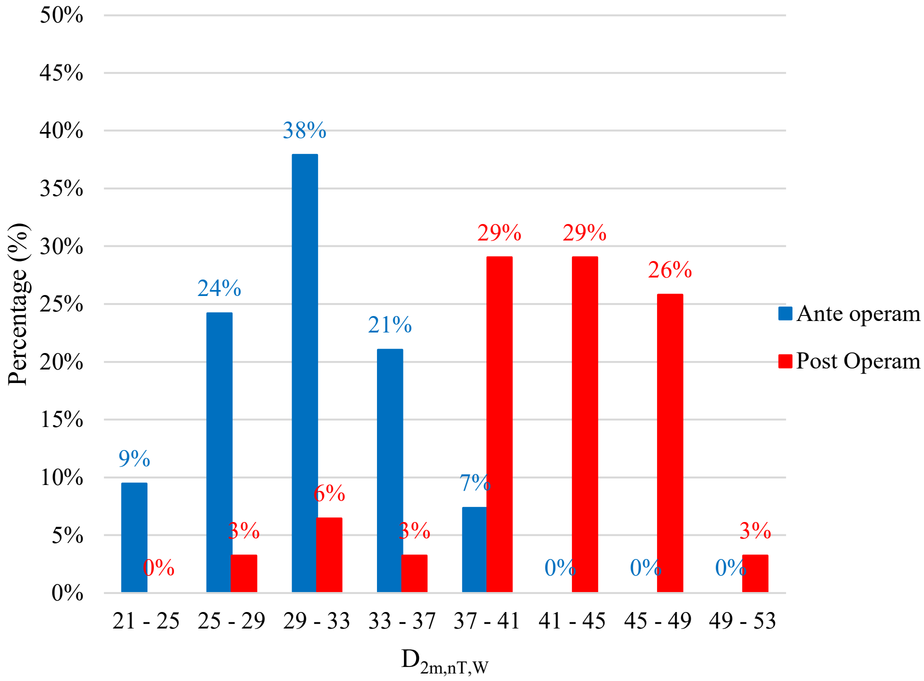

Figure 4 - Percentage distribution of classrooms with respect to the rating of the façade sound insulation before and after the refurbishment.

It can be concluded that, in the current state, Italian schools seldom fulfil the limit values given by the standard. At the same time, refurbishment interventions to improve acoustics are usually rather simple to perform and can almost guarantee the fulfilment of the enforced requirements.

5. CONCLUSIONS

Since the publication of the national decree (DM 11/10/2017) for public buildings, with its reference to the technical standards UNI 11367 and UNI 11532 for the verification of acoustic requirements, interest in the classification scheme and acoustic requirements has increased in Italy, after a long period of low attention due mainly to the crisis in the construction sectors. The reuse and refurbishment of existing buildings is one of the sectors with the highest potential for development for construction firms and insulation materials manufacturers.

The aim of any classification scheme, similarly to the energy sector, is to create a mechanism of continuous improvement of the quality of buildings under the pressure of buyer demands, but the time required to improve the constructing techniques can take several years. In order to obtain this result, a classification scheme needs to be comprehensible to the buyers, reliable and not too laborious to apply. For the building acoustic sector, this is not an easy task. One possibility seems to be a procedure based on the expected minimum performance criteria. The possibility to make preliminary calculations, using also the BIM modelling, maintaining the measurements for the final verification, could facilitate the objective.

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