# Applying different acoustical standards in South-Tyrolean schools

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**Summary**
In this paper the authors present the experiences in the application of different Italian circulars and decrees, national Italian standards, the German standards DIN 18041:2004-05 "Acoustic quality in small and middle-sized rooms" [1] and DIN 18041:2016-03 "Acoustic quality in rooms – requirements, recommendations and indications for planning" [2].
Experiences are based on measurements and evaluations of reverberation time, direct STI-PA and community noise, in teaching rooms, sport halls, playgrounds and dressing rooms in schools and in child care facilities and nursery schools, in all types of public and private schools.
The different standards consider targeted reverberation times in classrooms in unoccupied as well as in occupied conditions.
The authors discuss some examples and show how different revisions of the German DIN 18041 can lead to quite different conclusions in terms of acoustical requirements.

## 1. Background

The Autonomous Province of Bozen/Bolzano - South Tyrol is situated in the north of Italy. The Environment Agency as part of the local autonomy administration in this local context has a wide range of activities. The activities include air pollution control, water, waste and soil, food safety, hydropower, energy-conservation and public health. The laboratories of the Environment Agency always are involved when public institutions such as municipalities and schools need chemical analysis or noise measurements.
The most requested noise measurement in living spaces is the measurement of the reverberation time T in teaching areas and in classrooms in nursery, primary and secondary schools.
The acoustical quality in schools is related to reverberation times and echo and to background noise level. Good speech clarity and intelligibility is very important for all pupils. It becomes more important when the teaching language is not in the mother tongue, when teaching foreign languages and when teaching pupils with special educational needs and hearing impairment.

First reports regarding room acoustics measurements found in the archives of the Environment Agency of Bozen/Bolzano stem from the eighties and were related to classrooms. In the early nineties the school system in Italy changed and canteen kitchens and refectories were introduced. The reduction of human noise in these loud areas was effected introducing sound absorption surfaces in the refectories. In the year 2010 the Environment Agency of Bozen/Bolzano started an awareness raising campaign for the betterment of room acoustics in schools.

## 2. Description and method

All measurements reproduced and discussed in this paper were taken after requests coming from the schools or municipalities. That means that the headmasters of the schools had already decided to improve the quality of the room acoustics.

The measurements of the reverberation times were taken according to the standard ISO 3382-2:2008 [3]. The measurements were taken in the unoccupied classrooms with the engineering accuracy level of measurement and evaluating 20dB of reverberation time T. The noise level was generated from the clapping board applying the impulse excitation method or from the dodecahedron loudspeaker reproducing a sine sweep signal generated by the acoustic measurement system.

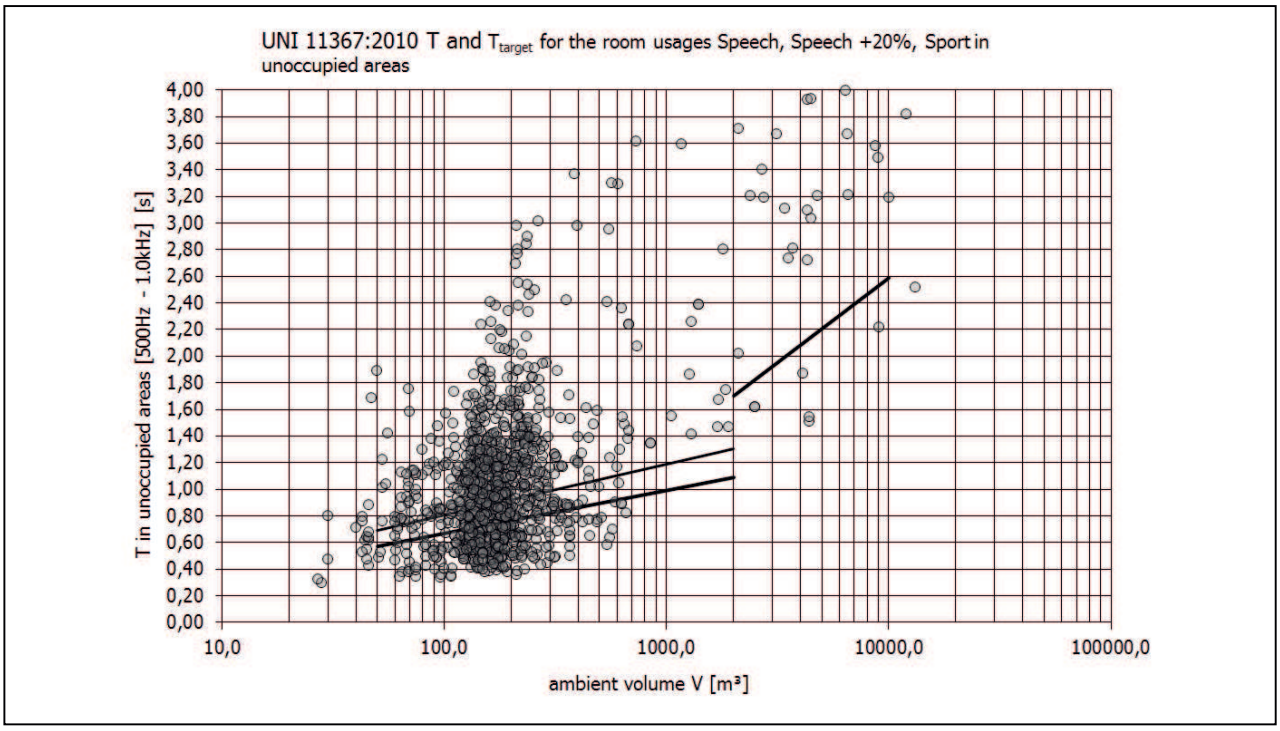


Figure 1. Evaluation of T (mean value 500Hz - 1.0kHz) for 1.000 classrooms in kindergartens and schools

## 3. Circulars, decrees and acoustic performance standards

In the Circular N. 3150 dated 22/05/1967 [4] the Italian Government fixed the requested reverberation time: 1,2 seconds for classrooms and 2,2 seconds for sport halls expressed as a mean value from 250Hz to 2.0kHz in unoccupied areas. In the Ministerial Decree "School Building Guideline" dated 18/12/1975 [5] targeting reverberation times for teaching rooms were introduced. They depend on the room volume of the classroom and on frequency and are referred to the unoccupied condition. These "optimum" reverberation times were applied as guidelines and not as limit values for reverberation times in schools. This interpretation was confirmed by the Decree dated 05/12/1997 [6]. The legal position wasn't and isn't still clear for the authors.

The province of Bozen/Bolzano has been granted a wide range of self-government. Thus in the year 2009 the School Building Guideline of South Tyrol [7] was updated. With the updating the standard DIN 18041: 2004-05 became the acoustic performance standard for reverberation times in teaching spaces like classrooms in kindergartens and schools, practice rooms, seminar rooms, lecture rooms and conference rooms. The reverberation time in teaching spaces needs to satisfy the state of the art/technology. The provincial School Building Guideline is not limited to the new school buildings but also applies to conversion and refurbishment work of school buildings. Therefore the acoustics performance standard for school buildings in the province of Bozen/Bolzano became different from national performance standards.

In July 2010 the Italian standard UNI 11367 [7] was released. In an informative attachment the "optimum" reverberation times for the room usage "Speech", "Speech +20%" (250Hz-4.0kHz) and "Sport" in unoccupied areas expressed as a mean value from 500Hz to 1.0kHz (black straights in Figure 1) were illustrated. The optimum reverberation time for "Speech" in unoccupied areas (UNI 11367) corresponds to the room usage "Teaching" in occupied areas + 0,2 seconds (DIN

18041:2004-05). The remark on the standard DIN 18041, that reverberation time $T_{target}$ in unoccupied areas should not be more than 0,2 seconds above $T_{target}$ in occupied areas, maybe was a reason for this coincidence. This remark was discussed in the German standard DIN 18041:2015-02 [9] and then abolished in the updated version of the German Standard DIN 18041:2016-03, because it was a source of misinterpretation. The reverberation times measured in the unoccupied rooms only with the presence of the technicians are recalculated to the occupied condition applicating the sound absorption areas given in the Appendix of the standard DIN 18041:2016-03 for the pre-schooler, for the pupils up to 11 years and for the pupils and adolescents respectively, whereby room occupation of 80% is presumed.

In the year 2013 in the province of Bozen/Bolzano a working group composed of technical experts from educational authorities, local authorities, health protection, associations of the parents of disabled pupils and pupils with hearing impairment and special educational needs, defined the rules to guarantee school access for all pupils following the Equality Act and fixed those in an agreement [10]. In order to fulfil the duties of pupils with hearing impairment the school administration bodies must respect the acoustic performance standard described in the School Building Guideline of South Tyrol. German standard DIN 18041:2004-05 had already defined reverberation times $T_{target}$ in teaching spaces for pupils with hearing impairment and special educational needs as well as when the teaching language is not in the mother tongue.

In April 2014 the Italian standard UNI 11532 [11] was published. This national standard contains a list of targeted reverberation times $T_{target}$ and limit values for reverberation times in the different states in Europe and all over the world. The reported Italian standard refers to the reverberation times limits published in the year of 1967.

The Acoustical Society of Italy AIA published in the year 2017 the Guideline for the correct development of school buildings [12].

## 4. Results and discussion

In Figure 1 and Figure 2 1.000 measurements in classrooms and 100 measurements in movements areas in nursery schools and sport halls in schools in the province of Bozen/Bolzano are illustrated. All of them are measurements performed on request of municipalities and schools. Before a pupil with hearing impairment or special educational needs attends nursery school or mainstream school the teaching rooms are tested by the authors for reverberation times.

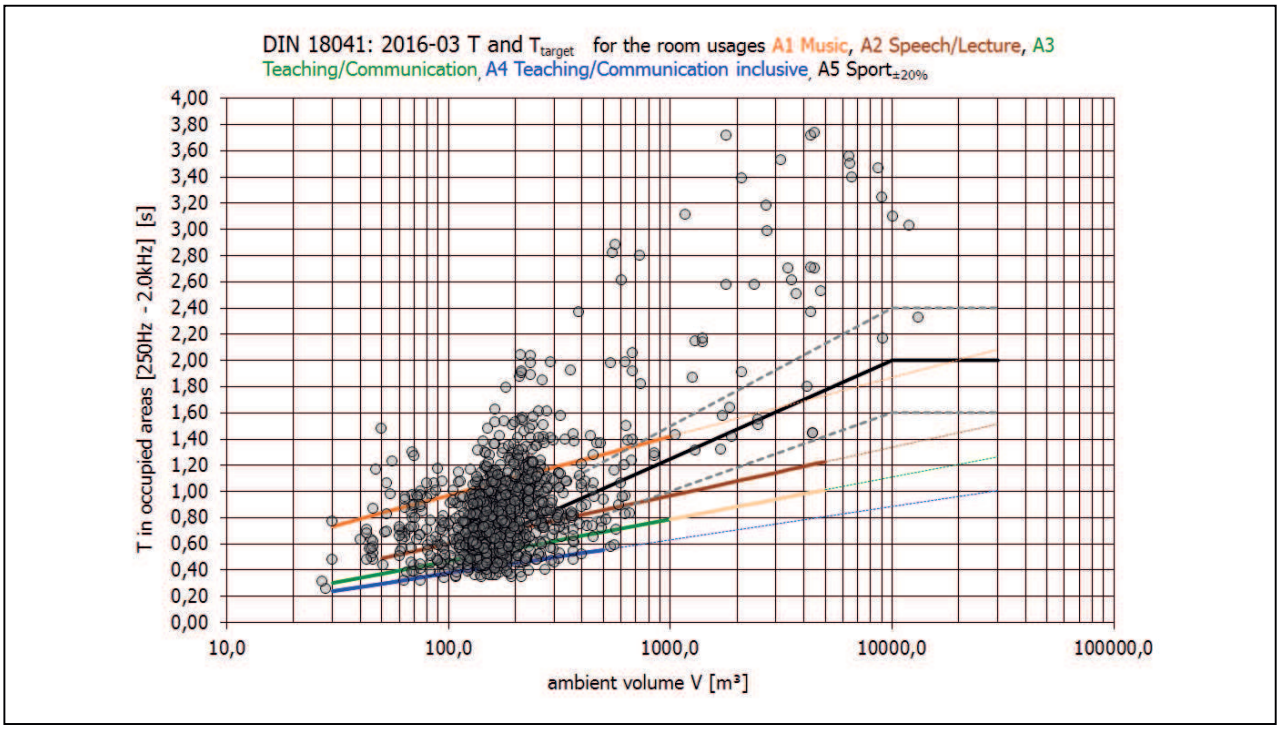


Figure 2. Evaluation of T (mean value 250Hz - 2.0kHz) for 1.000 classrooms in nursery schools and schools and $T_{target}$ for different room usage of rooms of category A

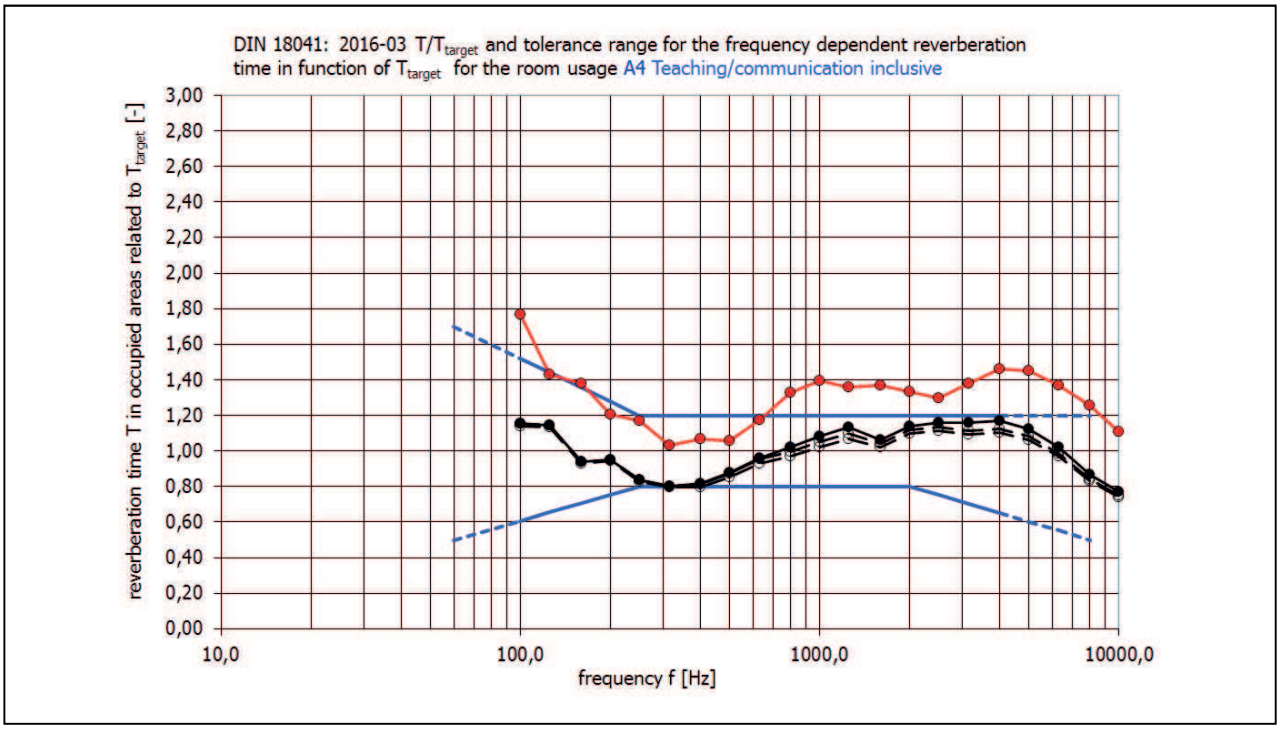


Figure 3. Evaluation of $T/T_{target}$ for 2 different movement areas (frequencies 100Hz-10.0kHz)

This happens in the previous school year to guarantee enough time to implement the acoustical refurbishment. The acoustical refurbishments are developed and controlled by a private acoustics consultant who usually measures the reverberation times after the acoustical refurbishment. These measurements don't appear in these figures.

Figure 1 shows that the limit value of 1,2 seconds for reverberation times in classrooms isn't a strict limit. The state of the art/technology allows shorter reverberation times. Most sport halls don't comply with the 2,2 seconds limit value.

The evaluation of reverberation time related to the targeted reverberation time $T_{target}$ in teaching rooms is always carried out over all frequencies from 100Hz to 10.0kHz and recalculated to the condition of occupied areas in accordance to the standard DIN 18041:2016-03.

In Figure 3 the frequency tolerance of $T/T_{target}$ is represented by the blue lines and corresponds to ± 20% between 250Hz and 2.0kHz.

For the rating of the measured reverberation time the standard DIN 18041:2016-03 uses entire octave bands analysis (125Hz-4.0kHz) whereas the authors utilize one-third-octave bands (100Hz-10.0kHz).

For a clearer presentation of a large number of results the authors decided to represent the mean values from 250Hz-2.0kHz in Figure 2. The state of the art are reverberation times measured in classrooms in kindergartens and in schools below the straight green line (room usage A4 Teaching/Communication inclusive) for pupils with hearing impairment, and reverberation times below the straight brown line for unimpaired pupils.

The previous evaluation assuming a tolerance of $T_{target}$ in ± 20% is an incorrect simplification because frequency tolerance of ± 20% is defined for $T/T_{target}$ between 250Hz and 2.0kHz.

Most sport halls don`t respect requested $T_{target}$ for the room usage A5 Sport.

The measurements of 2 movement areas in nursery schools are reported in Figure 3 in terms of $T/T_{target}$ instead of calculating the ratio of equivalent absorption area A to room volume V. For the "black" movement area $T/T_{target}$ is recalculated presuming an occupation of 15 pre-schooler, 15 pupils up to 11 years and 15 pupils and adolescents respectively.

The room volume of the movement area is 252m³. At the frequency of 1.0kHz difference of reverberation time between unoccupied and occupied areas is 0,03s for pre-schooler and 0,05s for adolescents. When satisfying $T_{target}$ for room usage A4 Teaching/communication inclusive in typical classrooms with typical occupation the correction from unoccupied to occupied areas is negligible. For longer reverberation times the

difference of reverberation times can became 0,2s or even longer. The remark of the withdrawn German standard DIN 18041:2015-02 that reverberation time $T_{target}$ in unoccupied areas should not be more than 0,2 seconds above $T_{target}$ in unoccupied areas is correct for some combinations of reverberation time, room volume and occupation, but wrong in most conditions.

room volume of 420m³ are illustrated as green and blue squares (recalculated as ratio A/V). The "red" movement area respects the requirement for a teaching room of category A3 Teaching/communication +20%, but doesn't fulfil the recommendations of A/V for a room of category B5. What's the reason for this? $T_{target}$ depends on the room volume and A/V depends on the room height.

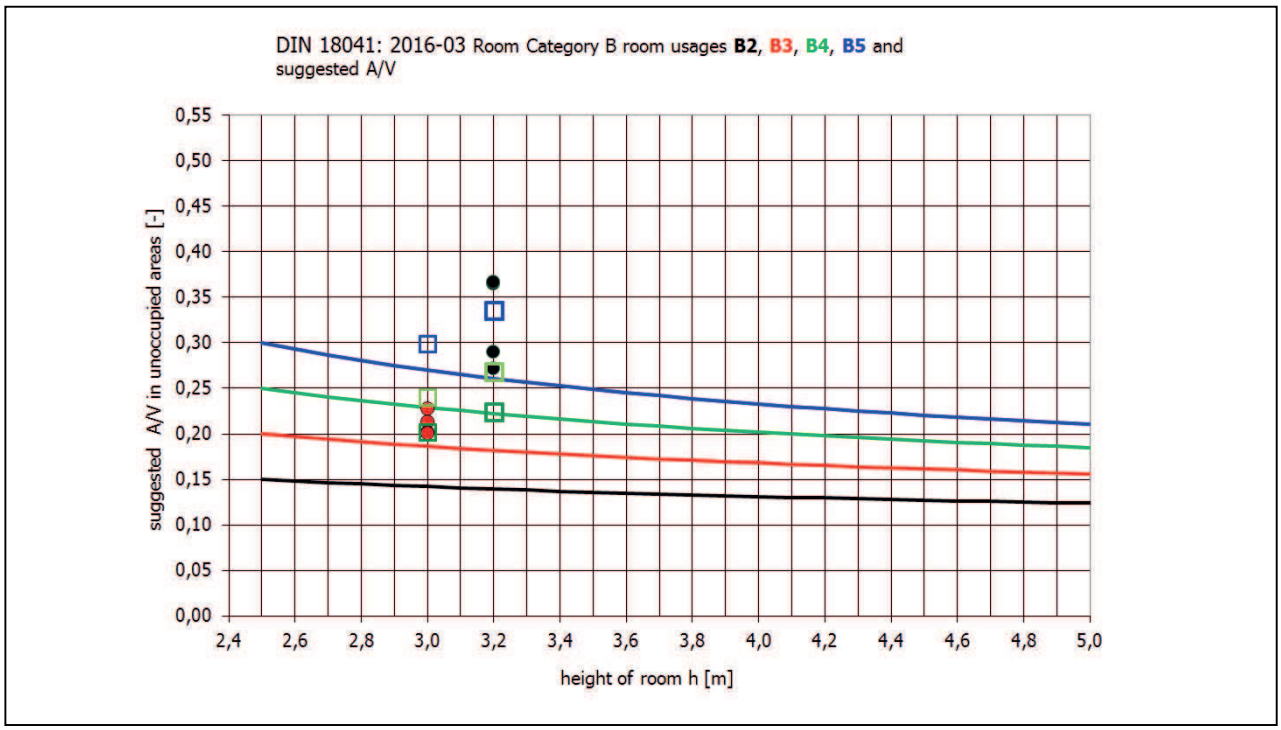


Figure 4. Suggested ratio A/V for rooms of category B2-B5 and results of measurements in 2 movement areas with different height and different room volume expressed as ratio A/V for room usage B5.

Figure 4 shows the correct evaluation of 2 movement areas in nursery schools as ratio of A/V. For the rooms of category B the German standard DIN 18041:2016-03 doesn't fix requirements in term of targeted reverberation times, but makes recommendations in the form of guidance values. The guidance value is the ratio A/V that depends on the height of the room and the room usage. Movement areas in nursery schools are rooms of category B5. The "red" movement area has a room height of 3m and a room volume of 420m³. The recommended ratio A/V is 0,27. This ratio A/V isn't reached at the frequencies 250Hz-500Hz-1.0kHz-2.0kHz illustrated as red balls. The reverberation time $T_{target}$ for A4 Teaching/communication inclusive, A3 Teaching/communication and A3 Teaching/communication +20% calculated for a

Also figure 5 prooves that the "red" movement area fulfills the requirements of $T/T_{target}$ for the room usage A3 Teaching/communication for each frequency.

The "black" movement area has a room height of 3,2m and a room volume of 252m³. The recommended ratio A/V is 0,26. This ratio A/V is reached at the frequencies 250Hz-500Hz-1.0kHz-2.0kHz illustrated as black balls. $T_{target}$ for a room volume of 252m³ with the room usage A3 Teaching/communication is 0,60s. The calculated ratio A/V for room volume=252m³, room height=3,2m and T= 0,60s is 0,27.

## 5. Conclusion

The authors had the experience first to work with national decrees and school building guidelines where reverberation times in schools were evaluated in unoccupied areas and then applying standards for the teaching rooms in occupied areas. The German standard DIN 18041:2016-03 isn't

designed for concert halls, orchestra halls, sport halls with audiences but typically for teaching rooms in schools and nursery schools. Therefore the recalculation of the measured reverberation times from unoccupied areas to occupied areas isn't very time-consuming, given the number of the pupils present during the school lessons.

Considering the German standard DIN 18041:2016-03 it`s difficult to explain to the school-users, like schoolmasters and teachers, the difference between rooms of category A and rooms of category B and the difference between requirements and recommendations. Movement areas in nursery schools mostly have similar room volumes and furnishings like the classrooms or playrooms.

particularly interesting for technicians and acoustics consultants.
The German standard DIN 18041:2016-03 is very detailed. However open space teaching areas in schools, gathering rooms in kindergartens, playrooms, playgrounds in halls and corridors couldn't be standardized neither in the province of Bozen/Bolzano nor in Europe. It's very important to understand the effective usage of the room or the open space area. So the authors evaluated open space teaching areas as room of category A but in other cases even as room of category B. There are particular situations where a clear classification according to the standard is difficult. This dilemma is shown in Figure 4 and has been already discussed in chapter 4. When a movement area in a nursery

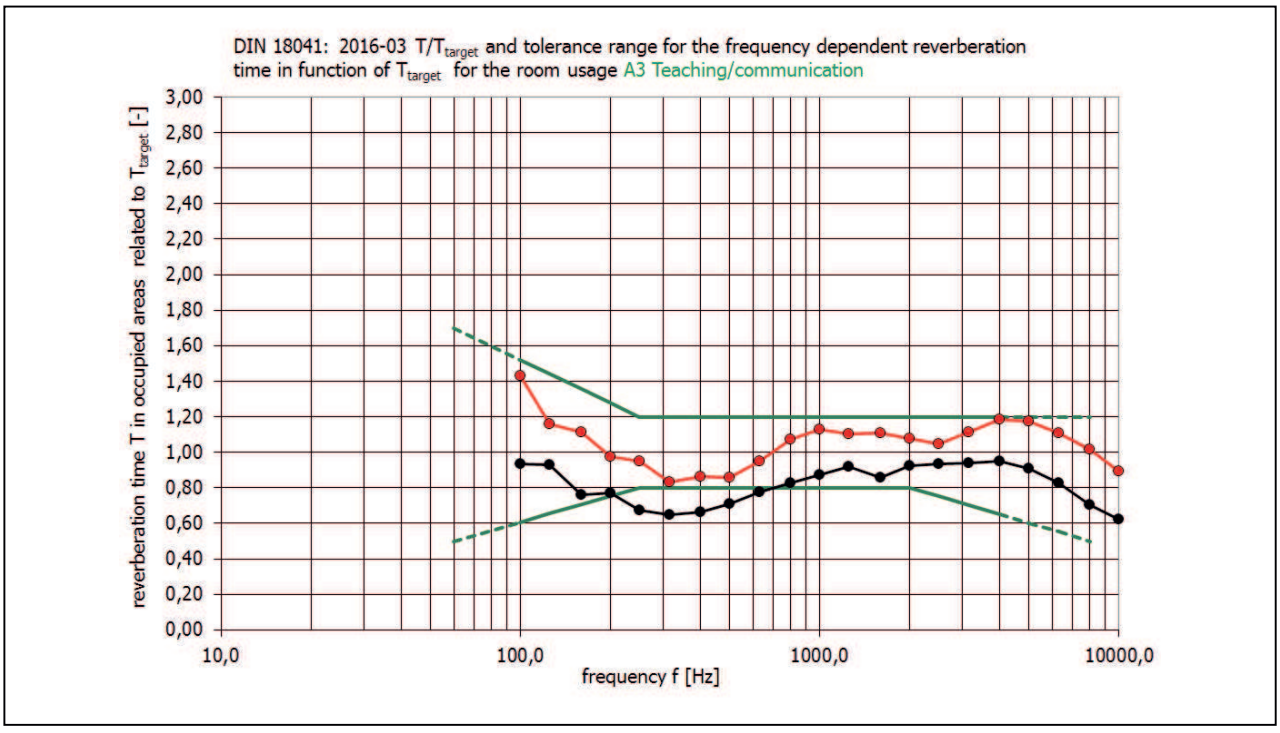


Figure 5. Evaluation of T/T$_{target}$ for 2 different movement areas (frequencies 100Hz-10.0kHz)

It's very difficult to explain to the school-users why there are only fixed recommendations of ratio A/V for movement areas in nursery schools and targeted reverberation time are not required.
The reverberation time and the targeted reverberation time are terms that are understood. The recommendation for rooms of category B expressed as a ratio of equivalent absorbent surface to room volume is impossible to understand by school-users. This recommendation approach is

school satisfies the requirements for a room of category A3 Teaching/communication, but doesn't satisfy the recommendations of ratio A/V for the room of category B5, what should be the rating for this teaching area?

The need for building owners, architects, engineers, acoustics consultants and planners are national laws or decrees that refer to explicit and updated national or international standards.
National laws and decrees should automatically refer to the currently updated technical standard as state of the art/technology. There is no more need to

rewrite laws and decrees when the technical standards are updated. The Guidelines for the correct development of school buildings from the Acoustical Society of Italy AIA are already moving in this direction.

The aim for acoustics consultants and planners should be to protect health and care of pupils, occupational safety for teachers and to enforce studying in a modern multilingual society.

A good acoustical room standard enhances the participation and the development of everybody's potentialities.

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## References

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[2] Standard -DIN 18041:2016-03 Hörsamkeit in Räumen – Anforderungen, Empfehlungen und Hinweise für die Planung.

[3] Standard - UNI EN ISO 3382-2:2008 Acoustics - Measurement of room acoustic parameters - Part 2: Reverberation time in ordinary rooms.

[4] Circular - Circolare del Ministro dei Lavori Pubblici N. 3150 del 22/05/1967, recante i criteri di valutazione e collaudo dei requisiti acustici negli edifici scolastici.

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