On the reliability of room acoustics simulation models: A case study of multi-purpose performance halls

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Abstract
A key objective of the present contribution is to emulate the paucity of detailed input data at the outset of a room acoustics simulation process. To this end, four existing multi-purpose performance halls were selected and respective acoustic models were generated. Thereby, in the absence of certified material data, the relevant input information was based on the available qualitative architectural documentation. Reverberation time and sound level distribution were measured and independently simulated using a room acoustics modelling tool. The comparison of the measurement results with the initial as well as modified simulation results contribute to the exploration of acoustic simulation tools’ reliability.

Key Innovations
- This contribution compares predicted and measured values of room acoustics performance variables, which is expected to provide useful information concerning the potential and limitation of room acoustics simulation tools.
- The findings of the paper, together with the outcome of related research efforts, represent a further step toward identifying recurrent sources of errors in room acoustics simulation.

Practical Implications
In the last decades, the capability of room acoustic simulation techniques has steadily increased. Nonetheless, as with other simulation areas, sources of uncertainty must be addressed. Investigations that compare predicted and measured values of acoustical parameters can provide practically relevant information on the reliability of room acoustics simulation tools.

Introduction
Room acoustical simulation tools can predict various parameters with regard to the acoustics of an indoor space (Christensen et al., 2016; Mahdavi, 2019). The capability of those tools has clearly increased within the last decades (Vorländer, 2010). However, similar to other building performance simulation areas, sources of uncertainty must be considered (Vorländer, 2013; Pilch, 2020). Acoustical simulation models require input data regarding, for instance, the geometry of the indoor space, furnishing, as well as surface materials and their corresponding properties (Christensen et al., 2016). Nonetheless, in some cases detailed information with regard to these parameters is not available (Vorländer, 2013; Mahdavi, 2019). This can especially occur in an early design stage and requires the users of simulation tools to make educated assumptions. Comparing acoustical measurements to the predicted simulation results can shed light on the potentials and limitations of room acoustics simulation tools. If done on a large scale, such studies can provide information, among other things, on recurrent sources of error (Bork, 2000; Jakic et al., 2019; Mahdavi et al., 2008a, b). Hence, the trustworthiness of room acoustics simulation processes can gradually improve in the long run. This contribution presents an instance of such a study, which is embedded in a broader effort to analyse the room acoustics performance of a specific type of indoor space, namely multi-purpose performance halls. Such venues have recently gained increased importance. Given rising construction costs and urban municipalities, contemporary performance halls are frequently conceived for more than one purpose. This represents also additional challenges with regard to acoustically relevant aspects of the design process of multi-purpose spaces. Related issues have been addressed in detail in a number of pertinent publications (see, for instance, Gao et al., 2020).

For the purposes of the present contribution, four existing multi-purpose performance halls in the city of Vienna (Austria) were considered. In a first step, the selected halls were modelled in a commercially available room acoustics simulation application and the values of two common room acoustics variables (reverberation time and sound level distribution) were obtained to capture the spatio-temporal behaviour of the sound field in the rooms. To emulate the design support simulation use case, the input for the simulation models were derived solely based on available plan documentation and applicable construction practices of the buildings’ erection period. In any case, no detailed information was available concerning the relevant acoustic properties of the room enclosure elements.

Next, room acoustics measurements were conducted in these halls. The simulated values were compared to measured results. Additional simulation runs were conducted to improve the room acoustic simulation models. The results provide an overview concerning the scope and magnitude of the initial simulations' errors. The iterative model modification step is as such not relevant to the design support scenario (other than the case of room
acoustics retrofit scenarios pertaining to existing buildings). Nonetheless, it supports the effort to identify common reasons why certain assumptions in the simulation model can result in smaller or larger predictive errors. Note that, given the limited typology and extremely small number of halls in the present study, no claim is being made concerning the generalization potential of the obtained findings. Rather, the objective is – as alluded to before – that a potential future meta-study based on the results of a large number of similar case studies can provide users with insights and guidance as to which aspect of the simulation model generation process require special attention and additional care.

Method

Four different multi-purpose performance halls, located in Vienna, Austria, were selected to conduct the study (Figures 1 to 4). Henceforth we refer to these halls as HE, KA, KS, and RB. Table 1 provides some basic information with regards to these halls.

Initial simulations

The geometry of the multi-purpose performance halls was modelled in a CAD tool. To this end, available architectural documentations, obtained from the respective institutions’ archives, were used. Note that the geometric modelling process involved certain simplifications. This included, for instance, some small decorative elements in the wall areas. The resulting simplified models are depicted in Figures 1 to 4. These models were exported to a commercially available room acoustics simulation software (Odeon, 2011). Note that the simulations in this study were not conducted with the latest version of this software. As mentioned before, the simulation runs (as well as the measurements) focused on two variables relevant to room acoustics performance, namely reverberation times and sound pressure distribution in the rooms. These variables provide basic information regarding the spatial and temporal distribution of the acoustical energy field. There are of course many other performance indicators in the area of room acoustics. The value of many of those can be generated using simulation applications. In the present contribution, we focused on the above two indicators, for which we had the possibility to obtain measured results. The initial simulations were conducted for an unoccupied state and typical room acoustics variables (reverberation time and sound level distribution) were obtained. Reverberation times were simulated for octave band frequencies (125 to 8000 Hz). Simulated sound pressure levels were expressed in dB(A) units.

Input data assumptions with regard to the geometry and enclosure materials were based on architectural documentation and general information regarding the applicable historical construction practices. Material selections for the initial simulations were restricted almost entirely to those entailed in the software's material data base (Odeon, 2020). This conscious decision was motivated in part by the intention to emulate simulation use cases relevant to early design stages.

![Figure 1: Floor plan, section and 3d illustration of HE with the location of speaker (○) and microphones (●).](image1)

![Figure 2: Floor plan and 3d section of KA with the location of speaker (○) and microphones (●).](image2)

![Figure 3: Floor plan and 3d section of KS with the location of speaker (○) and microphones (●).](image3)

![Figure 4: Floor plan and 3d section of RB with the location of speaker (○) and microphones (●).](image4)

<table>
<thead>
<tr>
<th>Code</th>
<th>HE</th>
<th>KA</th>
<th>KS</th>
<th>RB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum seat capacity</td>
<td>872</td>
<td>250</td>
<td>300</td>
<td>60</td>
</tr>
<tr>
<td>Volume [m³]</td>
<td>17000</td>
<td>3880</td>
<td>3420</td>
<td>1225</td>
</tr>
<tr>
<td>Construction date</td>
<td>1854</td>
<td>1863</td>
<td>1816</td>
<td>1889</td>
</tr>
<tr>
<td>Retrofit date</td>
<td>1998</td>
<td>1900, 2010</td>
<td>2007</td>
<td>2020</td>
</tr>
<tr>
<td>Typical usage</td>
<td>theatre dance music</td>
<td>concerts theatre</td>
<td>concerts talks seminar</td>
<td>bar theatre concerts</td>
</tr>
</tbody>
</table>

Table 1: Basic information of the multi-purpose halls.

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In these cases, detailed information. It can be assumed that such early design simulation models would frequently make use of the tool-integrated material data base. Consequently, we adopted the same approach for the initial simulations of this study. Concerning scattering coefficients, the default values of the Odeon database (0.05) were used.

Table 2 summarized the constituent model elements for the initial simulation of all four multi-purpose performance halls. Figures 1 to 4 illustrate the positions of the virtual speaker and virtual microphones. The grid of virtual microphones was formed in accordance with the size and capacity of each hall. The microphones were positioned at a height of 1.2 m. Moreover, a virtual omnidirectional speaker ("Omni.SO8", 80 dB) was used for the simulation (Odeon, 2011).

Most selected software settings were based on the software’s default values. Concerning the calculation parameters, Odeon offers the possibility to select among specific simulation settings in terms of three different categories (Survey, Engineering, and Precision). For the simulations of this case study, the category “Precision” was selected. For this category, the number of late rays recommended by Odeon were 72016 (HE), 54528 (KA), 66880 (KS), and 165728 (RB). The assigned values for room temperature and relative humidity were 22°C and 66%, respectively.

**Measurements**

The reverberation times (octave band frequency spectrum) as well as sound level distribution patterns (in dB(A)) were measured within the halls. These measurements were conducted at an unoccupied state. An industry standard omni-directional speaker was used as the sound source. Detailed technical information concerning this source (sound power spectrum, sound emission directivity) may be obtained from Norsonic (2020). The position of the sound source as well as the grid of the microphones correspond to the aforementioned simulation input assumptions (see Figures 1 to 4).

The measurements were conducted in accordance with the Austrian release of the ISO standard (ISO, 2009). However, the measurements involved a deviation from this standard as follows. Whereas a complete set of data was obtained for a speaker position in each space, due to circumstances pertaining to the scheduling of the measurements (specifically, time constraints), only a sample of data could be obtained for a second speaker position. However, a control comparison of the results of this sample with the complete measurements did not reveal a difference outside the measurement uncertainty range. Temperature and relative humidity during the measurements were in the range 22°C ± 1°K and 40 ± 10%, respectively. The spectrum of the background sound level was at all positions and all frequencies at least 30 dB below the generated signal for the measurement of the reverberation time. Likewise, the generated signal for the measurement of the sound level distribution in the rooms was at all positions at least 30 dB above the background noise level at the applicable frequency filter. This was verified based on the measured background sound levels in the halls. As such the background sound levels was fairly similar across all four halls. They can be represented using the respective spectral distribution in RB as follows: 35 dB (125 Hz), 26 dB (250 Hz), 20 dB (500 Hz), 15 dB (1000 Hz), 12 dB (2000 Hz), and 8 dB (4000 Hz).

**Table 2: Overview of initial input assumptions regarding main model constituent (surfaces, materials). The numeric identifiers pertain to the material library of the software application and can be assessed online (Odeon, 2020).**

<table>
<thead>
<tr>
<th>Components</th>
<th>HE</th>
<th>KA</th>
<th>KS</th>
<th>RB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Floor</strong></td>
<td>Wooden parquet [3002], Tufted pile carpet [7003]</td>
<td>Wooden floor on joists [3004]</td>
<td>Floating wooden floor [3001]</td>
<td>Marble or glazed tile [2001], Carpet on concrete [7004]</td>
</tr>
<tr>
<td><strong>Walls</strong></td>
<td>Painted plaster surface [4002], Cotton curtains [8005], Curtains, densely woven [8014], Drapes, heavy velour [8010], Drapes, medium velour [8009], Solid wooden door [10007]</td>
<td>Painted plaster surface [4002], Concrete block, painted [104], Marble or glazed tile [2001], Double glazing [10003], Blinds in front of glass [8100], Curtains, cotton cloth [8011], Drapes, heavy velour (Harris, 1991) [8010], Solid wooden door [10007]</td>
<td>Plywood on battens fixed to solid backing [3062], Concrete block painted [104], Ordinary window glass [10006], Solid wooden door [10007]</td>
<td>Painted plaster surface [4002], Plaster with wallpaper [4003], Double glazing [10003], Blinds in front of glass [8100], Curtains cotton cloth [8011], Drapes heavy velour [10007]</td>
</tr>
<tr>
<td><strong>Ceiling</strong></td>
<td>Painted plaster surface [4002]</td>
<td>Painted plaster surface [4002]</td>
<td>Plywood paneling [3068]</td>
<td>Smooth concrete, painted or glazed [102]</td>
</tr>
<tr>
<td><strong>Unoccupied seating</strong></td>
<td>Heavily upholstered chairs [11056]</td>
<td>Upholstered chairs with cloth cover [11006]</td>
<td>Wooden chairs (Fasold and Veres, 2003)</td>
<td>Upholstered chairs with cloth cover [11006]</td>
</tr>
</tbody>
</table>
Comparison with measurements and simulation model modification

The outcome of the on-site measurements was compared with the initial simulation results. In three of the four cases, the visual inspection of the graphically depicted comparisons implied that the divergence between measurements and simulations was in part significant. For these three cases, a second round of simulations were performed. However, please note that, a standardized calibration exercise was not the central intention of the study. Given the absence of empirical information on absorption coefficients of the actual room surfaces (specifically no reliable information on scattering coefficients), a calibration exercise would not identify the "tool-centric" (e.g., algorithmic) sources of uncertainty. The reason for this is the conflation of the tool-centric sources of error with errors implicit in input assumptions (mainly, material-related specifications). Rather, material-related modifications undertaken in the second set of simulations, were intended to identify common trends why certain assumptions can result in smaller or larger predictive errors. The modified materials of the simulation models (i.e., assumed alternative sound absorption coefficient values of certain enclosure and seating elements) are summarized in Table 3. Within this iteration phase, material-related information beyond the tool’s database was used. In case of KA and RB, an additional geometrically relevant modification to the initial model (coupling of the main space to an adjacent area) was made.

Simulations for occupied conditions

The initial project plan included measurements of acoustical parameter under occupied conditions. However, this became untenable, due to unforeseen circumstances (Johns Hopkins, 2020). Nonetheless, additional simulations were conducted to obtain an approximate impression of the reverberation times in occupied state. Toward this end, the “calibrated” simulation models (for KS, KA, and RB) were used for three of the halls (see Table 2 and 3 for the respective assumptions). The simulation results were compared to the recommended reverberations times for multi-purpose rooms for speech and music (Fasold and Veres, 2003).

Table 3: Modified material-related assumptions for the second simulation set (numeric identifiers refer to Odeon (2020)).

<table>
<thead>
<tr>
<th>Component</th>
<th>Halls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KA</td>
</tr>
<tr>
<td>Floor</td>
<td>Hollow wooden podium [3000] (instead of 3004)</td>
</tr>
<tr>
<td>Walls</td>
<td>Concrete block, painted [104] (instead of 4002)</td>
</tr>
<tr>
<td>Ceiling</td>
<td>Plaster, gypsum, or lime, rough finish on lath [4035] (instead of 4002)</td>
</tr>
</tbody>
</table>

Results

Figures 5 to 8 illustrate the spatially averaged measured and simulated frequency-dependent reverberation times in the four halls (both initial and second simulation runs). Note that in three cases (HE, KA, RB) simulated values for the occupied and unoccupied halls were very close. Hence, they were not differentiatied in the figures. Figures 9 to 12 provide information concerning the sound pressure level (in dB(A)) distribution in the halls (unoccupied state). Thereby, the y-axis depicts the sound level in terms (Lrel) of a relative scale (see equation 1).

\[ L_{rel} = L - L_{rp} \] (1)

Herein \( L \) denotes the measured/simulated sound pressure level at position i and \( L_{rp} \) the measured/simulated sound pressure level at a reference position (the microphone position closest to the sound source).

The x-axis depicts the relative distance (\( D_{rel} \)) of various receiver positions (Di) from a reference receiver location (\( D_{rp} \)) closest to the sound source (see equation 2).

\[ D_{rel} = D_{i} - D_{rp} \] (2)

Herein \( D_{i} \) denotes the distance of the microphone position i to the sound source and \( D_{rp} \) the distance of a reference position (the microphone position closest to the sound source) to the sound source.
Discussion

As Figures 5 to 8 suggest, the comparison of the measurement results with the initial simulations suggests that the reverberation time values are frequently overestimated. To capture this observation in a compact form, Table 4 entails information concerning the deviation of simulated reverberation time values from the corresponding measurements (both unoccupied). This information is expressed in term of relative errors (RE) calculated (see equation 3).

\[ RE = \frac{T_m - T_s}{T_m} \cdot 100 \]  

(3)

Herein \( T_s \) and \( T_m \) denote simulated and measured reverberation times respectively. Note that Table 4 includes in addition to the frequency-dependent relative errors, also the relative error of an averaged value of reverberation time (\( T_m \)) over three octave-band frequencies (125, 500, and 2000 Hz).

In case of the hall HE, the relative errors are within a ±20% range. As alluded to before, a standardized calibration exercise (for instance, as discussed Postma and Katz, 2016) was not the intention of the study. The tolerance range of ±20% was deemed applicable, as it has been used as a practical tolerance benchmark of deviations pertaining to practical applications (Fasold and Veres, 2003; ÖNORM, 2005). As a result, further simulation iterations were not pursued in case of HE. The largely positive values of the relative errors underline the
The aforementioned tendency of the initial simulation models toward overestimation of the reverberation time values. This tendency persisted throughout the second set of simulations, however the magnitude of relative errors decreased significantly (see Table 4). For instance, after the second set of simulations, the relative errors of T₂ were reduced from 63, 33, and 26 % down to 15, 5, and 13 % for halls KA, KS, and RB respectively. However, even after the second set of iterations, these relative errors, which are equivalent to JND (just noticeable difference), are higher than the 5% limit specified according to ISO 3382-1 (2009) (see Table 4). A comparable general pattern can also be observed when comparing the measured sound pressure levels to the simulated values (see Figures 9 to 12). To further pursue this point, Figure 13 depicts the differences between the simulated and measured sound pressure levels (in dB(A)) for all receiver positions in the four halls in terms of a boxplot. Thereby, the difference for the first and second sets of simulations (applicable to KA, KS, and RB) are shown separately.

The consistently positive values of the simulation errors point in this case to the simulation models’ tendency to overestimate the sound pressure levels. As in the case of HE, the median of the errors (differences between measured and simulated sound levels) was within 1 dB, a second set of simulations were not conducted. The second simulation iterations led to a significant reduction of the median of the errors from 2.1 and 2.7 dB down to 1.0 and 0.5 dB for the halls KA and KS respectively.

Table 4: Relative errors (in %) of simulated reverberation times for the four halls (unoccupied).

<table>
<thead>
<tr>
<th>Hall</th>
<th>Iteration</th>
<th>Frequency [Hz]</th>
<th>T₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>125</td>
<td>250</td>
</tr>
<tr>
<td>HE</td>
<td>I</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td>KA</td>
<td>I</td>
<td>119</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>KS</td>
<td>I</td>
<td>-47</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>-14</td>
<td>-21</td>
</tr>
<tr>
<td>RB</td>
<td>I</td>
<td>10</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>2</td>
<td>10</td>
</tr>
</tbody>
</table>

In case of KA, the initial simulation showed significantly overestimated reverberation times in the lower frequencies (see Figure 6). In this simulation, the floor of the podium area was assumed to be "Wooden floor on joists" (Odeon, 2020), neglecting thus sound transmission through this component. A closer look at the actual circumstances suggested that the alternative assumption "Hollow wooden podium" would render a more realistic assumption. Moreover, an adjacent area, which is separated with a curtain from the main space, was not included in the initial simulation model. In the modified simulation model, this area was assumed to be acoustically coupled to the main hall. The modifications had a significant influence on the reverberation time at lower frequencies and brought the simulated values (reverberation times and sound pressure level) closer to the measurement results.

The initial simulation of KS showed underestimated reverberation times at lower frequencies and significantly overestimated values at higher frequencies (see Figure 7). In the initial simulation model, “Plywood on battens fixed to solid backing” and “Plywood panelling” had been assigned to the arcs and ceiling respectively (Odeon, 2020). The suboptimality of the choices for arcs and ceilings was anticipated and subsequently confirmed by the measurements.

As, more suitable material selections for these components could not be located in the software's material library, other sources needed to be identified. Subsequently, "Periodic battens" (Choi, 2013) was assigned to the arcs. Furthermore, a customized material profile (adapted from Fasold and Veres, 2003) was assigned to the ceiling. The latter customization was based on information provided in Fasold and Veres (2003) on the behavior of combined porous absorbers and vibrating plates. These modifications clearly reduced the magnitude of the simulation model’s errors (see Figure 7).

In case of RB, initial simulations resulted in slightly overestimated reverberation times. The initial simulation model had not included an adjacent hallway that is separated from the main hall with a curtain. In the second simulation, this hallway was assumed to be acoustically coupled to the main space. Moreover, two small openings to another hallway were also not included in the initial simulation model. In the modified simulation these openings were treated as fully sound absorbing. The adjusted simulation model yielded reverberation times closer to the measured values. This, however, did not translate into a noteworthy improvement of sound level predictions.

As mentioned before, simulations were also conducted for occupied conditions. In case of HE, KA, RB, no significant difference was detected between simulated reverberation times under empty and occupied conditions. This is logical, as, given the upholstered seating in these halls, the assumed absorption coefficients were rather similar for both conditions. However, in case of KS, the seating comprises of individual wooden chairs. Thus, the occupied state brings about a clear change in the
acoustics, as indicated by the respective values of simulated reverberation times (see Figure 7). Reverberation time has been conventionally used as one of the relevant criteria in the evaluation of room acoustics. Thereby, recommended values are suggested depending on the room function and volume. Table 5 shows suggested desirable reverberation times (for different room usage scenarios) adjusted for the volume of the four multi-purpose performance halls (Fasold and Veres, 2003).

When comparing the given (measured or simulated) value of the reverberation time with the recommended values, certain tolerance ranges are deemed applicable. For this purpose, we refer in our study, to pertinent literature as well as common standards in Germany and Austria (Fasold and Veres, 2003; ÖNORM, 2005; DIN, 2016). These tolerance ranges are, relative to the reverberation time at 500 Hz, ±20% (for the frequency range 250 to 2000 Hz). At higher frequencies, the lower limit is extended down to -50% (at 8000 Hz). The tolerance ranges are also adjusted at lower frequencies. Specifically, at 63 Hz, the applicable tolerance range is between +20% and +70% for music and between -20% and +70% for speech (Fasold and Veres, 2003). Depending on the volume of the halls, the recommended reverberation times for multipurpose rooms (Topt) are 1.65, 1.4, 1.38, and 1.2 s for HE, KA, KS, and RB, respectively.

Figure 14 puts the simulated reverberation times in the four halls (occupied conditions) in the context of the above-mentioned recommended values (and their tolerance ranges). Thereby, the y-axis shows the ratio of the simulated reverberation time (Ts) to the respective recommended values (Topt) at 500 Hz. Looking only at the recommendations explicitly formulated for multipurpose halls, the examined halls generally meet the requirements, with the exception of frequencies over 500 Hz in case of KS, and frequencies below 250 Hz in case of RB.

![Figure 14: Ratio of the simulated reverberation times in HE, KA, KS, and RB to recommended values for multipurpose rooms for speech and music.](https://doi.org/10.26868/25222708.2021.30183)

**Conclusion**

This contribution compared simulated reverberation times and sound pressure levels to measured values. The comparison was conducted for four different unoccupied multi-purpose performance halls in Vienna, Austria. The aim was to contribute to efforts regarding the exploration of the potentials and limitations of room acoustics simulation toward design decision support. Such exploration needs to address the circumstance that, in early stages of design, detailed information regarding the acoustical properties of relevant room elements and surfaces is frequently not available. To more closely reflect the circumstances of such a simulation use case, the initial simulation models were mainly generated based on existing plan documentations of the selected halls. Moreover, the definition of acoustically relevant material properties was consciously restricted to the choices entailed in the deployed simulation application's material data base. As such, given the age of the selected buildings, the existing documentations did not include data on acoustical properties (i.e., sound absorption and scattering attributes of room enclosure components) and an in-situ measurement of such properties was not an option. In this context, it is important to underline the previously mentioned aspect of the pursued research strategy, namely to conduct the initial simulation without any knowledge of the subsequent measurements in the halls.

Comparing the measurement results with the initial simulations revealed, especially in three of the four cases, an overestimation of the simulated reverberation times and sound pressure levels. For these three halls, modified simulation models were generated. This step was informed by a closer look at some of the specific features of the halls’ existing situation. This led to modification of some of the material-related assumptions, whereby alternative sources of data were considered. Moreover, in two cases, the modelled spatial domain was extended to accommodate coupling effects with adjacent spaces.

The revised simulation models of the three halls yielded results closer to the measurements. For instance, the relative errors of the computed mean reverberation times were reduced from 63, 33, and 26 % down to 15, 5, and 13 %.

Measurements could not be performed under occupied conditions. Nonetheless, the modified simulation models were used to model the presence of audience. The resulting reverberation times were compared with applicable recommendations. The results imply, by and large, compliance with the requirements for multi-purpose halls. As mentioned at the outset, the aim of the present study was to contribute to the efforts that explore the reliability of room acoustics simulation models. It is thus of importance, to implicitly mentioned a number of the study's limitations. The nature of the selected buildings reflects the motivation of a larger ongoing investigation of the acoustics of the multi-purpose halls. As such, given the very small number of buildings examined to date, the presented results are not suggested at all to represent a general tendency. Moreover, due in part to the constraints associated with the measurements' logistics, only two of the many relevant indicators of the halls' acoustical behavior could be taken into consideration. Another limitation concerns the absence of measurements under occupied conditions. Even though considered in the initial research design, such
measurements could not be conducted due to the aforementioned unforeseen and uncontrollable circumstances. Furthermore, testing the limits of simulation model calibration using exact information on the as-is absorption properties of room surfaces was not possible, given missing necessary technical diagnostics capability for this purpose. Nonetheless, the results of the study, together with those conducted in the past – and to be conducted in the future – can contribute to the incremental improvement of practice-oriented approaches to room acoustics simulation.

A typical instance of such improvement potential relates to the significant influence of material-related assumptions on the simulation result, highlighting thus the importance of special care in related choices. In design scenarios, availability of detailed manufacturers’ information (including measurement reports) could be of decisive importance in view of predictive accuracy of simulations. In retrofit scenarios, availability of diagnostics tools for in-situ measurements could significantly facilitate the calibration process. The results also suggest the importance of the resolution of the room geometry and spatial adjacency assumptions. Specifically, the representation of building component geometries that deviate from simple planar surfaces in the simulation model can be a formidable challenge and hence a further source of error in predictions. Such components include, among others, those with noteworthy geometric articulations or elaborate three-dimensional structures such as trusses and lattices. These observations, along with the results of similar past and future studies represent a step toward the identification of recurrent sources of error in room acoustics simulation and the formulation of respective remedies, contributing thus to a gradual improvement of the trustworthiness of design and retrofit decision making in this domain.

References


