Definition of a Method of Limits of the Simplification of a Hall Model in a CAD System to Diminish Falsification of Acoustic Simulation Results

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Abstract. *During the modelling, because of the sometimes complex architectural shape of halls, we were forced to introduce simplifications in order to carry out calculations and simulation operations on these halls, as the calculation software requires plane surfaces. This paper presents a developed tool adapted on a CAD modelling system (AutoCAD), which defines an "average limits" of the model simplification operation in order to control and diminish the falsification of calculation and simulation results on this model, such as the architectural acoustic simulation.*
The process of the elaboration and the adjustment of the simplified models of the Grand Theatre of Bordeaux (GTB) based on acoustical measurements and their calculation results are described in detail in a previous article (Kouzeleas and Semidor, 2001). The analysis process of the consequences of the hall model simplification on the acoustical simulation results and the applied simplification methods are described in a PhD thesis (Kouzeleas, 2002).
This article is based on this analysis process in order to apply it on several simplified models of the Amphitheatre of the Architecture School of Bordeaux (Amphi-EAPB). The comparison in a CAD system (AutoCAD) of the acoustical calculation results and the areas after simplification of the simplified models of these two halls made with AutoCAD, via the developed tool adapted on the AutoCAD, permit to define a "limits average of a hall model simplification" before the falsification of these calculation results.

Keywords. *Calculation Cad Program Integrated Development ; Design Process ; 3D Modeling ; Performance Simulation ; Acoustic simulation results*

Introduction

The necessary simplification of the hall models for many technical reasons and due to specific requirements of software in order to proceed in calculations and in simulations, such as the architectural acoustic simulation, present, naturally, some falsification of the calculation and simulation results. The more a model is simplified, the more the calculation and simulation results are falsified.

This research applies an analysis process of the simplification on four simplified models of the amphitheatre of the Architecture School of Bordeaux (Amphi-EAPB) in comparison with the four simplified models of the Grand Theater of Bordeaux (GTB) and their acoustic results. The analysis of the simplification process (areas calculation, etc) in comparison with its impact to the acoustic calculation results define a “tolerance scale” in order to examine the influence of the simplification to the calculation results so as to diminish any falsification.

The modelling of the Amphi-EAPB is realized with AutoCAD and the calculation acoustic results, concerning all the simplified models, are estimated using CAD-Acoustic software which is developed in the context of a PhD thesis (Kouzeleas, 2002). The calculation acoustic results of the GTB are estimated using Epidaure software with the same configuration to all the models (flytower and pit closed) (Kouzeleas and Semidor, 2001)

Simplification consequences and methods

The consequences of the hall model simplification on the acoustical simulation results and the applied simplification methods are already described in detail in a PhD thesis (Kouzeleas, 2002).

This analysis consists in comparing different types of areas on several simplified models of the same main hall after its simplification (fig 1). The first comparison concerns the consequences analysis of the evolution of the total area per material of each simplified model of the same hall. The second comparison concerns the consequences analysis of the area of different, gradually simplified, parts of the hall. The third comparison concerns the consequences analysis of the gradual simplification evolution of the hall’s total area.

The simplification methods consist in some principles of manual treatment of models (Fig 2). According to the first method, the area and the volume of the simplified part must be kept as close as

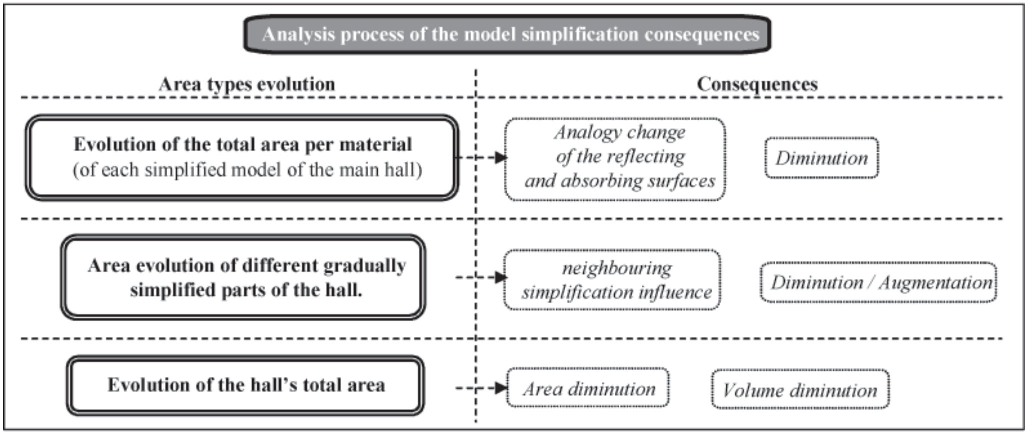


Figure 1. Analysis process of the model simplification consequences through examination of area types evolution

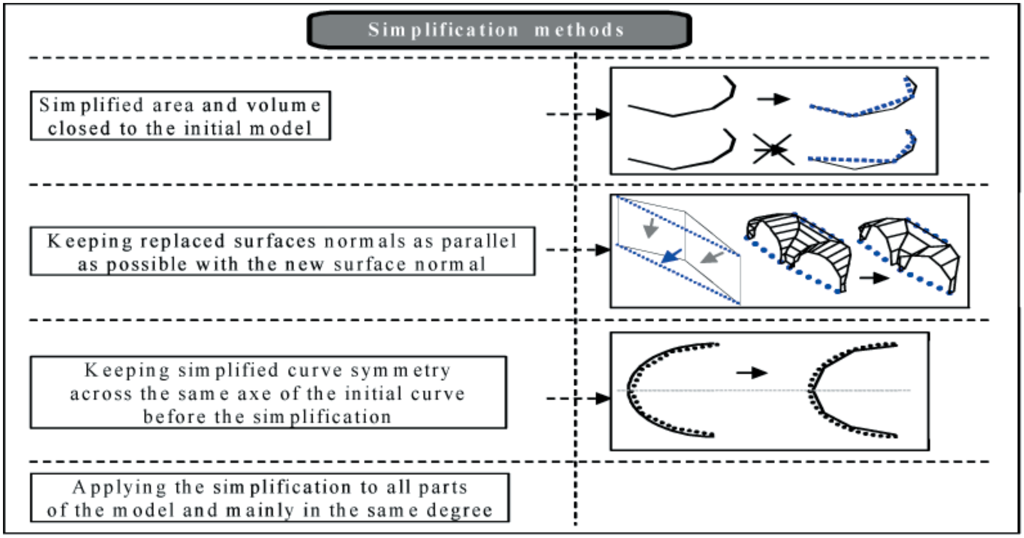


Figure 2. Simplification methods of models

possible to those of the initial model. The second principle consists in keeping the direction of the total sum of the Normals of the replaced surfaces as parallel as possible with the normal of the new surface. The third principle consists in keeping the symmetry of the simplified curve across the same axe of the initial curve before the simplification. The last principle is to apply the simplification to all parts of the model and, mainly, in the same degree, even if the simplification of some parts generate fewer consequences to the neighbouring parts.

Presentation of the models

The initial model of the Amphi-EAPB's hall has 2652 surfaces and is made in AutoCAD environment (fig. 3)

The four simplified models of the Amphi-EAPB in all degrees of complexity (mod 1 : 1135 surfaces - mod 2 : 938 surfaces – mod 3 : 842 surfaces – mod 4 : 602 surfaces) are the results of the simplification of the complete initial model. The next figure shows the results of the simplification from the initial model (2652 surf.) to the most simplified

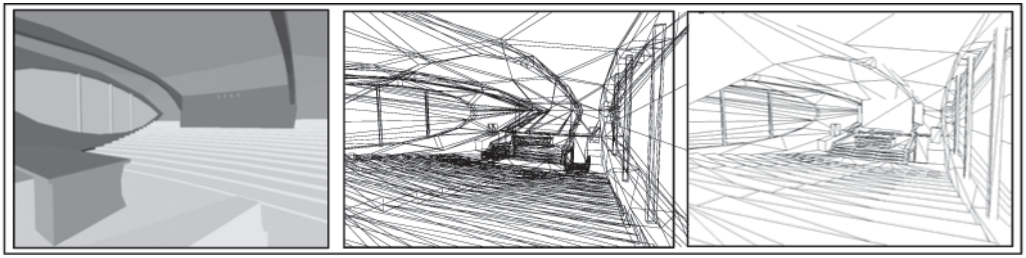


Fig. 3 – The initial model of the Amphi-EAPB

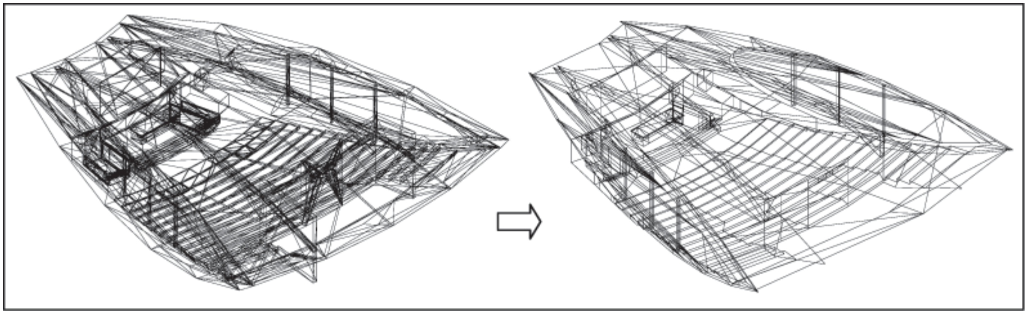


Fig. 4 – Simplification of the Amphi-EAPB from the initial model to the most simplified one

model n° 4 (602 surf.) (fig. 4)

The four simplified models of the GTB in all degrees of complexity (mod 1: 3466 surfaces, mod 2: 1784 surfaces, mod3 : 1220 surfaces, mod 4: 811 surfaces) are the results of the simplification of the complete initial model (26696 facets) (Kouzeleas, 2002) (Fig. 3). The modelling is also made with AutoCAD with the same configuration to all the models (flytower - pit closed) (fig. 5)

Analysis results of the model simplification consequences

Comparisons of areas after simplification

After the simplification of the architectural model for acoustical simulation, a comparative research shows what the consequences are concerning the modification of the total area of the surfaces. The total area per material after simplification very often presents a light diminution compared with the area before simplification (Fig. 6).

This change is often not very significant and it depends on the position and the repartition of the material into the hall. This is justified by the example of the apportionment of many materials : in the Amphi-EAPB's hall the "carpet on concrete" presents a diminution of 20,90% in its total area after simplification while the second material "oilcloth" presents a diminution of only 2,05% and the "windows" 0,00 % (Fig. 6 left); in the GTB's hall the first "wood 1" presents a diminution of 9,70 % in its total area after simplification while the second material "wood 2" presents an augmentation of 12,20 % in its area after simplification (Kouzeleas, 2002) (Fig. 6 right). The change of the total area per material can influence significantly the acous-

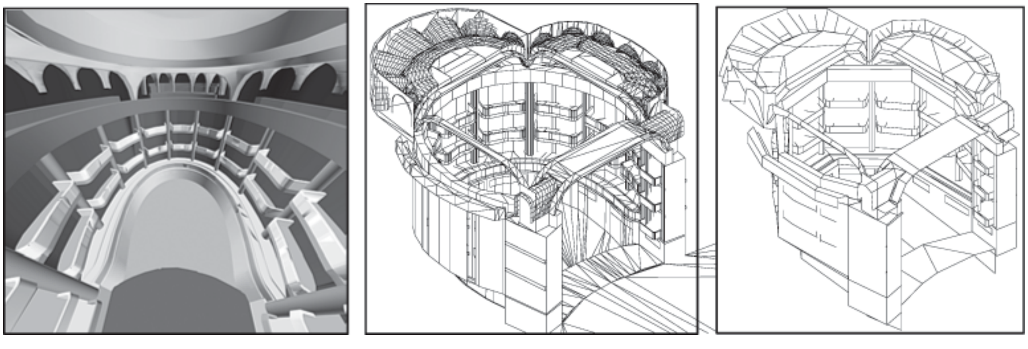


Fig. 5 – The initial model of the GTB (left) and the simplification from the most complex model n° 1 (middle) to the most simple one n° 4 (right)

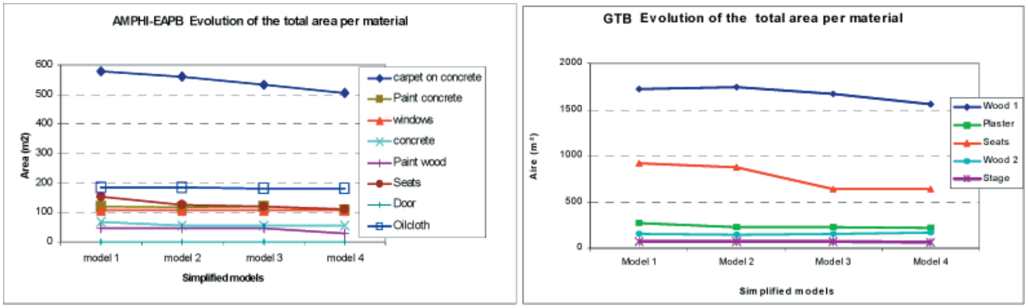


Fig. 6 - Total area occupied per material after simplification from the most complex model (mod. 1) to the most simple one (mod. 4), Amphi-EAPB (left), GTB (right)

tic results because it modifies the analogy of the reflecting and absorbing surfaces of the hall.

This result is, on the one hand, due to the repartition and the different position of these two materials, which influence in a, more or less, important way the change of the area of the surfaces after simplification, and on the other hand, due to the neighbouring of some parts of the hall that are more or less simplified. This means that, very often, the more one part of the hall is simplified, the more it generates an important simplification to the neighbouring part (Kouzeleas, 2002).

However, the area of the gradually simplified parts does not change considerably. Some examples show this evolution (Fig. 7).

The most important parameters after the simplification of the models are the total area of the simplified hall and its volume. These parameters influence considerably some objective criteria like the Reverberation Time (RT60) etc. The next figure shows the evolution of the total area of the gradual simplification of the models (Fig. 8).

During and after the simplification of the model, the diminution of the total area is almost inevitable. In this case, this diminution is 20,11% in the Amphi-EAPB (15,60 % in the GTB) starting from model 1 to model 4. This event, as a consequence, generates a diminution of the total volume of the model. The ratio of the total area and the volume can generate different rates of the RT60 and, of course, influence other objective criteria. In many cases, the more we simplify the model the smaller the RT is, because, very often, the diminution of the volume is less significant than the diminution of the total area.

After that, the comparisons of the RT60 with the other simplified models, using the same absorp-

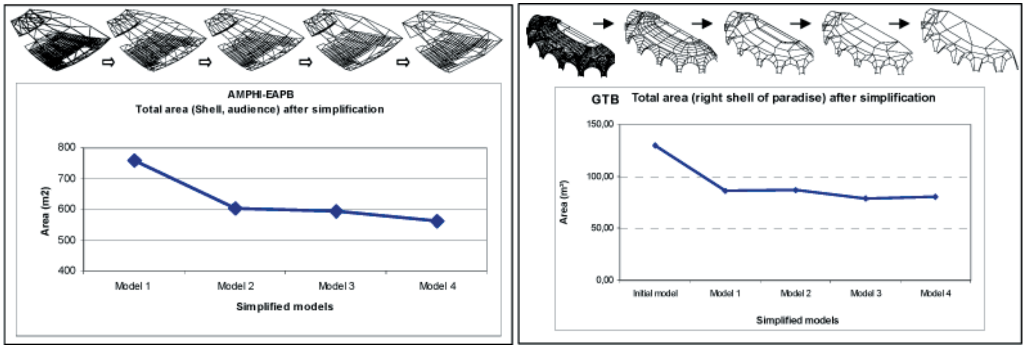
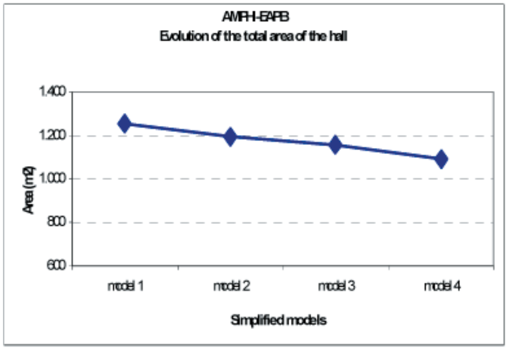


Fig. 7 – Evolution of the total area of the gradual simplification of one part of the hall (right shell of paradise), Amphi-EAPB (left), GTB (right)



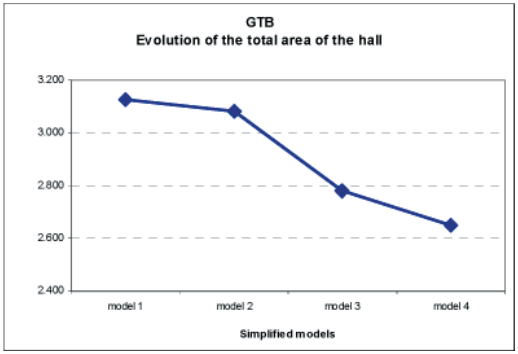


Fig. 8 – Evolution of the total area of the gradual simplification of the four models, Amphi-EAPB (left), GTB (right)

tion coefficient values, are presented in Figure 9.

Analysis of the simplification data

The statistics concerning the diminution of the areas after simplification in the two halls, in comparison with the calculation results are presented in this table (Table 1) :

Based on this table, we observe that the area diminution average of the materials and of the hall, influence considerably the acoustic results and each area simplification of the surfaces has an impact and is proportional to the acoustic results.

Automatization process via a proposed tool in a CAD environment

Components presentation

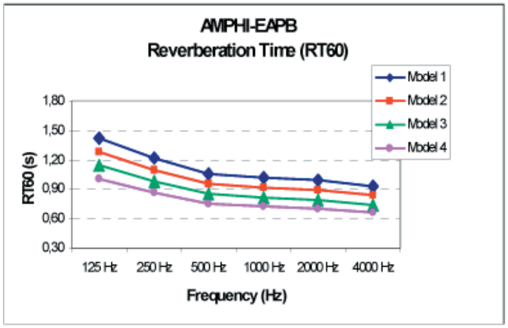
The simplification methods and all the previous analysis results of the model simplification consequences, concerning the acoustic results are taken into account to a proposed tool. This tool is realized with the Visual LISP and Visual BASIC programming code and it is adapted to the AutoCAD platform.

It consists of two components; the first one has to do with the automatization of the simplification of the models. For every simplification method a routine is developed which helps one during the simplification of the hall, to control, propose and respect as much as possible, the main proposed simplification principles in order to influence and falsify, as little as possible, the calculation results (fig. 10 left).

The second part of the proposed tool is based on a graphical comparison method of calculation results (Kouzeleas and Semidor, 2002). This comparison in graphical form, takes into account, on the one hand, the rates taken from the proposed tool after the computer analysis of the simplification data concerning the averages of the hall areas and on the other hand a scale deviation in percent which defines the tolerance of the change of the acoustic results (fig. 10 right).

	Area diminution average of the materials (%)	Total area diminution average of the hall (%)	Diminution average of the acoustic results (model to model) (%)
AMPHI-EAPB	13,01	14,26	10,7
GTB	14,13	15,6	11,11

Table 1. Area's simplification connection with the acoustic results



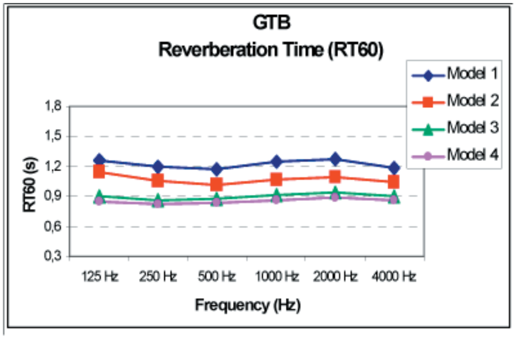


Fig. 9. Comparisons on the RT60 of the four simplified models, Amphi-EAPB (left), GTB (right)

Tolerance method definition

According to the scale deviation of the change of the acoustic results, a deviation of 5% of the rates of the acoustic calculation results, comparing to the optimal rates, is acceptable and does not "infect" the results; a deviation of 10% is tolerable and a deviation more than 10% influences considerably and changes the results (Kouzeleas and Semidor, 2002).

Based on this deviation scale, we define a tolerance deviation scale concerning the simplification of models in order to diminish the falsification of the acoustic simulation results. Based on Table 1, we observe that the tolerance deviation of 10% in the acoustic results corresponds to a deviation almost 15% of diminution of the area. The proposed approximate tolerance deviation scale about the model simplification & its impact to the acoustic results is presented below (Table 2)

Average limits method and acoustic software

The acoustic results of the same hall are often not the same if we use different items of acoustic software. Consequently, a definition of a method of limits in question depends on the results of the acoustic software we are going to use. According to the scale deviation of the change of the acoustic results, if the results between different items of acoustic software range between -+5% (acceptable) or between -+10% (tolerance limit) (fig. 11), the proposed tolerance deviation scale can be applied and gives reliable results.

Simulation of the results

The calculated rates of the materials area and the total area are automatically saved into sheets of Excel files. The integrated calculation code into the simulation module takes into account these calculated rates and compares them with the rates of the calculation of the acoustic results in order to define the tolerance deviation scale. The final Excel file includes connections between all the calculated rates in order to treat and display the results correctly in graphical form. The results are

Area diminution average of the hall (%)	Diminution average of the acoustic results (%)	Acoustic simulation results
8	5	Excellent
15	10	Tolerance
> 15	> 10	Falsification

Table 2. Approximate tolerance deviation scale about the model simplification impact to the results

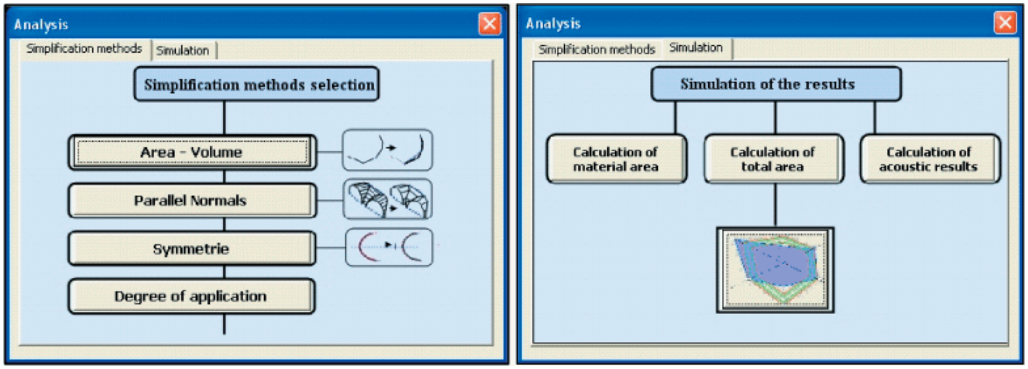


Fig. 10. Simplification methods component (left) & simulation component (right) of the proposed tool

presented in diagram describing the area diminution average of the hall in comparison with the tolerance deviation scale.

In the results diagram, the calculated rates form one area (here filled in blue color) in the center of the diagram ("acoustical rose") where each of the six axes which intersects with the other, corresponds to one frequency (from 125Hz to 4kHz for the RT calculation). This filled area is first of all compared with the limits of the first empty area (the two green lines in the center of four lines) corresponding to the tolerance deviation scale (deviation: - + 8%). When this filled area is placed between the green lines, the rate of the model simplification does not "infect" considerably the acoustic results ("excellent") (fig.12a-left); when it is placed between the red lines (deviation: - + 15%) the model simplification is tolerable concerning the falsification of the acoustic results ("tolerance") (fig.12b-middle); finally, when it is placed outside the final limits of the red lines either towards the outside or towards the inside, the model simplification generates a falsification of the acoustic results ("falsification") (fig.12c-right).

Conclusion

The diminution of the total area and the total volume is almost inevitable during and after an important simplification of the model. The consequence of this simplification is that the predicted results will be different from the measurements. The methods of the simplification of the models can influence and optimise or not the calculation results. The simplification of a model always influences the area per material and the total area of

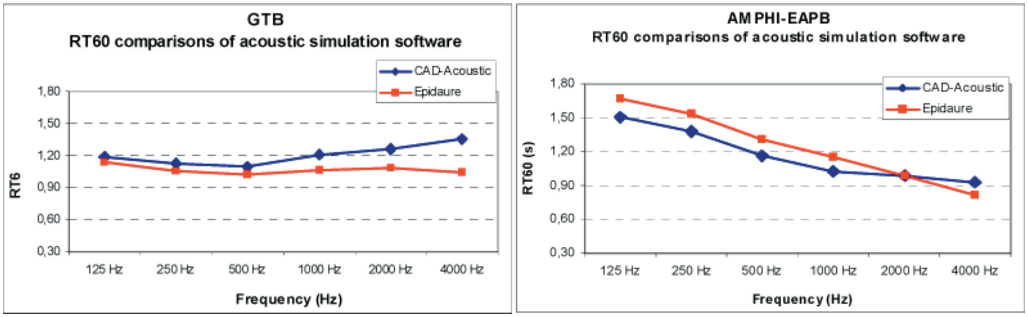


Fig. 11. Reverberation Time (RT60) comparisons of the Amphi (left) and the GTB (right) by using different acoustic software

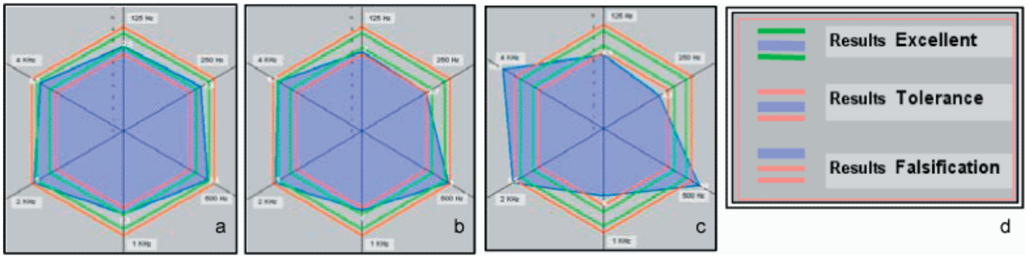


Fig. 12. Simulation of the model simplification results in graphical form

the hall. This diminution influence and falsifies the final results.

The area diminution average of the hall after the simplification (material or total area) has an impact to the acoustic simulation results. The comparison area diminution average of the hall with its impact to the acoustic simulation results defines an approximate “tolerance deviation scale” which describes the tolerance limits of a simplification to diminish the falsification of the acoustic simulation results.

The proposed “tolerance deviation scale” to diminish the falsification of the acoustic simulation results is based also on a scale deviation in percent, which defines the tolerance of the change of the acoustic results (deviation from -+ 5% to +- 10%).

According to the proposed scale an area diminution average of the hall of 8% generates a diminution average of 5% in acoustical results which is a very tolerable (excellent simplification without a significant falsification of the results). In the same way an area diminution average of the hall of 15% generates a diminution average of 10% in acoustic results (limits of tolerable simplification) and finally an area diminution average of the hall more than 15% generates a considerable falsification in the acoustic simulation results.

The method of limits in question, depends on the results of the acoustic software we are going to use; if the results between different items of acoustic software range between -+5% (acceptable) or between -+10% (tolerance limit) the proposed tolerance deviation scale can be applied and gives reliable results.

The simulation of the results describing the method in question is presented in a comparative graphical form. In this graphical form the area diminution average of the hall is compared with the proposed tolerance deviation scale in order to define graphically and approximately the level of the inevitable falsification of the acoustic results in order to diminish it and better control the simplification of the models.

The proposed tool developed in the AutoCAD environment which is automates on the one hand, the simplification methods in order to use them during the simplification of the models and optimize the operation and, on the other hand, it simulates the results, in a graphical form, in order to control the simplification and diminish the falsification of the results.

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