Assessment And Acoustic Enhancement Of A Multi-Purpose Venue With COMSOL Multiphysics.

Riccardo Balistreri[1], Martin Castrovinci[2], Gianpiero Majandi[3], Prof. Emilio Ruiz-Reina[4]

[1]AtlasIED, Phoenix, AZ
[2]Pragma Electro-Acoustics Ltd., Birkirkara, Malta
[3]Pragma Electro-Acoustics Ltd, Birkirkara, Malta
[4]University of Malaga, Spain

Abstract

This study focuses on the acoustic design of a multipurpose hall with a volume of approximately 3,000 m³, which is subject to strict architectural constraints. These constraints limit interventions to the suspended ceiling only. The primary objective is to reduce the reverberation time (RT60) to values of ≤1.4s while ensuring high acoustic quality across variable spatial configurations and diverse functional uses.
The methodology is structured into three main phases:
(1) A pre-intervention experimental measurement campaign conducted in accordance with ISO 3382.
(2) Predictive modelling using COMSOL Multiphysics® 6.3.
(3) Auralization model for the perceptual evaluation of Room Acoustic Simulations.
The consistency between the numerical model and in-situ measurements was validated by comparing octave-band decay curves and applying Schröder integration and linear extrapolation of the T30 parameter.
Analysis revealed a systematic reduction in reverberation time and significant improvements in parameters such as C80, D50 and STI within critical speech intelligibility frequency bands (500-4000 Hz).
However, alternative parameters to RT, such as C50, D50 and STI, were found to have significant limitations in simulation models, primarily due to source directivity, the absence of wave phenomena and the simplifications inherent in geometrical methods.
The entire study was conducted in compliance with ISO 3382-1, ISO 3382-2 and ISO 23591:2021, incorporating operational criteria derived from the Norwegian standard NS 8178. The findings demonstrate that a combined approach integrating in-situ measurements, numerical modeling and post-operam validation is a robust methodological strategy for acoustically optimizing complex environments. A final experimental verification phase is planned following the intervention to confirm the effectiveness of the acoustic treatment and the accuracy with which the simulation model represents the actual behavior of the treated space.

Reference

[1] ISO 3382, “Acoustics – Measurement of room acoustic parameters”, International Organization for Standardization.

[2] M. Kleiner, B.-I. Dalenbäck, and P. Svensson, “Auralization - An overview,” J. Audio Eng. Soc., vol. 41, no. 11, pp. 861–875, Nov. 1993.

[3] A. Buen, “Early design criteria for small multipurpose cultural houses,” in Proc. Baltic-Nordic Acoustics Meeting (BNAM), Bergen, Norway, May 10–12, 2010.

[4] S.-M. Lee, C.-J. Park e C.-H. Haan, “Investigation of the appropriate reverberation time in learning spaces for elderly people using speech intelligibility tests,” Buildings, vol. 12, n. 11, art. 1943, Nov. 2022.

[5] ISO 23591:2021, Acoustics – Acoustic quality criteria for music rehearsal rooms and spaces, International Organization for Standardization, Geneva, Switzerland, Sep. 2021

[6] NS 8178:2023, Acoustic quality criteria for spaces for music performance, Norwegian Standards, Oslo, Norway, Aug. 16, 2023.

[7] J. G. Olsen, “Acoustics in rooms for music rehearsal and performance – the Norwegian experience,” in Proc. Baltic-Nordic Acoustics Meeting (BNAM), Oslo, Norway, Jun. 2021, pp. 33–41.

[8] D. D. Rife, “Room acoustics measurements using MLSSA,” J. Acoust. Soc. Am., vol. 89, p. 1877, 1991.

[9] M. Kleiner and P. Svensson, “Room reverberation measurement by conventional methods and by the MLSSA measurement system,” J. Acoust. Soc. Am., vol. 89, p. 1877, 1991.

[10] C. L. Christensen, “Practical methods to define scattering coefficients in a room acoustics computer model,” Applied Acoustics, vol. 74, no. 3, pp. 295–302, Mar. 2013.

[11] C. L. Christensen, “A new scattering method that combines roughness and diffraction effects,” Acta Acust. united Acust., vol. 99, no. 3, pp. 482–492, May/Jun. 2013.

[12] A. Armani, RT60 — RT60: NWWin3 Operating Manual, NoiseWorks, ver. 3, 2024, p. 6.

[13] COMSOL, Geometrical Acoustics Module User’s Guide – 11.34: Ray Acoustics Model Settings, COMSOL Multiphysics® Reference Manual, Version 6.3.

[14] M. R. Schroeder, “New method of measuring reverberation time,” Journal of the Acoustical Society of America, vol. 37, no. 3, pp. 409–412, Mar. 1965.

[15] DRA Laboratories, MLSSA User Manual, Version 10WI Rev. 8, Sarasota, FL, USA, 2001, p. 123.

[16] J. Harvie-Clark and N. Dobinson, “The practical application of G and C50 in classrooms,” in Proc. Spring Conference: Acoustics 2013, London, UK: Institute of Acoustics, 2013.

[17] F. Brinkmann, L. Aspöck, D. Ackermann, S. Lepa, M. Vorländer, and S. Weinzierl, “A round robin on room acoustical simulation and auralization,” J. Acoust. Soc. Am., vol. 145, no. 4, pp. 2746–2760, Apr. 2019.

[18] J. Schütze, C. Kirsch, B. Kollmeier, and S. D. Ewert, “Comparison of speech intelligibility in a real and virtual living room using loudspeaker and headphone presentations,” Acta Acustica, vol. 9, art. 6, 18 pp., Jan. 21, 2025.

[19] R. A. Pillai, S. S. Murugan, and G. Gupta, “A Complete Analysis of Clarity (C50) Using I-SIMPA to Maintain Ideal Conditions in an Acoustic Chamber,” Sound & Vibration, vol. 56, no. 1, pp. 51–64, Jan. 2022.

[20] H. Onaga, Y. Furue, and T. Ikeda, “The disagreement between speech transmission index (STI) and speech intelligibility,” Acoustical Science and Technology, vol. 22, no. 4, pp. 265–271, 2001.

[21] Internal data, [Pragma Electro-Acoustics Ltd.], confidential internal report, 2025.

[22] B. F. G. Katz, “International round robin on room acoustical impulse response analysis software 2004,” Perception Située, LIMSI-CNRS, BP 133, F91403 Orsay, France.

[23] B.-I. Dalenbäck, “Engineering principles and techniques in room acoustics prediction,” in *Proc. Baltic-Nordic Acoustics Meeting (BNAM)*, Bergen, Norway, May 10–12, 2010.

Figures used in the abstract

Figure 1 : Venue in study.

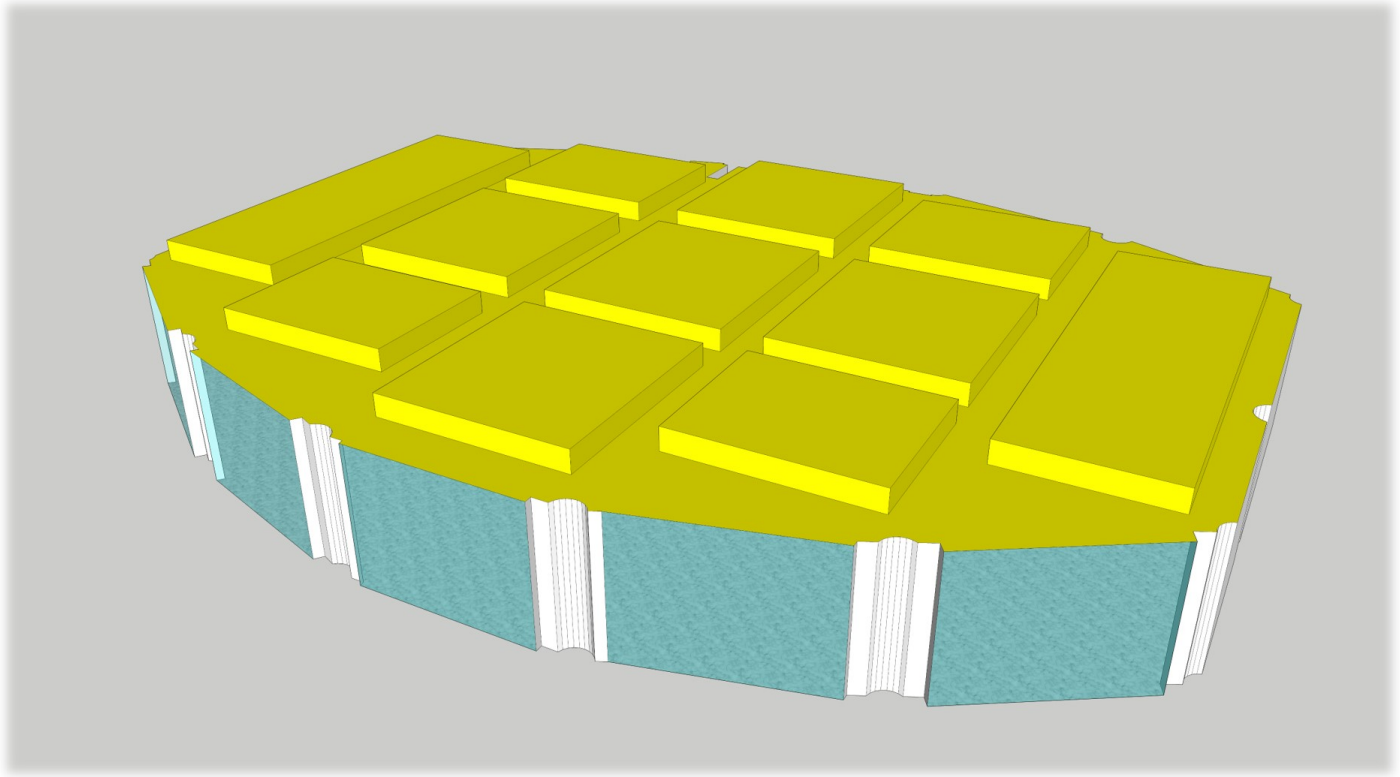

Figure 2 : 3d model of space.

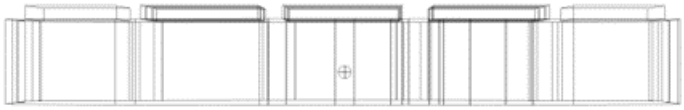

Figure 3 : Ray Tracing from source and receiver in same position as real measurements in the venue.

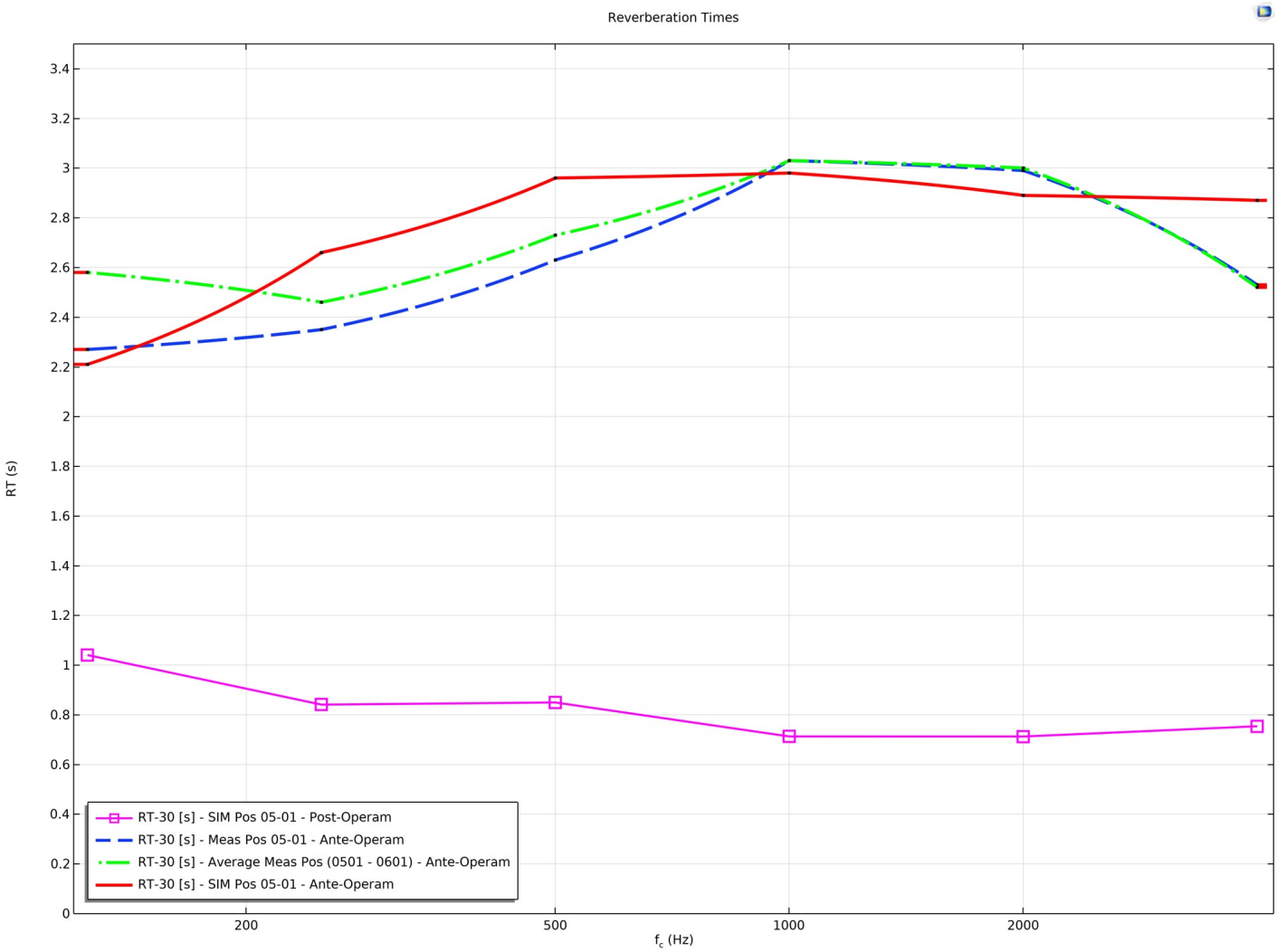

Figure 4 : Simulated reverberation times at position matching the measurements and new reverberation times after treatment applied in model.