DOI: 10.61782/fa.2025.0492

FORUM ACUSTICUM EURONOISE 2025

INTRODUCTION OF A GRASSHOPPER WORKFLOW FOR THE INTEGRATION OF THE ACOUSTIC ANALYSIS IN A MULTI-DOMAIN BIM MODEL

Andrea Gerbotto[1*] **Louena Shtrepi**[1] **Fabio Favoino**[1] **Arianna Astolfi**[1]
[1] Department of Energy, Politecnico di Torino, Italy

ABSTRACT

The growing demand for sustainable, energy-efficient buildings underscores the need for integrated modelling and simulation tools that support informed decision-making during early design stages. Among these, simulation of building physics performance, mainly acoustic analysis, has emerged as a critical focus area. Addressing multi-domain perspectives poses challenges, primarily due to interoperability issues and the varied data management approaches across specialised tools. This paper presents a workflow for integrating acoustic performance calculations within a BIM (Building Information Modeling) model. It details the development of an acoustic assessment tool in Grasshopper, utilising Rhino.Inside Revit, for preliminary evaluations of facade acoustic insulation. The tool supports the selection of transparent and opaque elements while accounting for potential conflicts with other performance criteria, such as thermal and lighting properties. Developed as part of the iclimabuilt project, this workflow aims to advance decision-making through seamless interoperability, enhancing efficiency, sustainability, and architectural performance outcomes.

Keywords: *BIM, BPS, facade insulation*

1. INTRODUCTION

A multidomain simulation workflow was developed, integrating Rhino.Inside® Revit to connect the BIM tool Revit with the Building Performance Simulation (BPS) tools in Grasshopper within Rhino. Specifically, 'Honeybee' was utilised for energy and daylighting simulations via EnergyPlus and Radiance engines. The interoperability between BIM and BPS was enhanced through the use of Python scripts, ensuring the accurate linkage of geometry and material performance parameters between Revit and Grasshopper. Additionally, the workflow was extended to incorporate acoustic analysis for façade sound insulation and the 'Bombyx' tool for Life Cycle Assessment (LCA). This expansion enabled a more comprehensive evaluation, including occupant comfort and the embodied energy of materials, which complemented the assessment of operational energy for cooling, heating, and lighting.

2. DEVELOPMENT OF THE RHINO.INSIDE REVIT SIMULATION WORKFLOW

A comprehensive analysis of the current workflow involving BIM models, either within authoring software or through external IFC-compliant tools, has been conducted to define the integration of acoustic simulations into the multi-domain workflow. This analysis demonstrates that there is great potential in integrating building and room acoustics into architectural models to make more informed decisions about acoustic characteristics in the design phases of a building; however, several challenges have so far prevented such large-scale integration [1].

Most studies focus on reverberation time calculations and, in some cases, impulse response and auralization, with a specific emphasis on environments such as auditoriums and classrooms. Some contributions have explored the connection between BIM and acoustic software:

**Corresponding author*: andrea.gerbotto@polito.it.

- Kim, Coffeen, and Sanguinetti [2] linked Revit with EASE to enhance collaboration between acousticians and architects;
- Mastino et al. [3] developed a workflow for integrating acoustic assessments into BIM processes;
- More recently, McGinley et al. [4] proposed an OpenBIM workflow to improve collaboration between designers and acoustic consultants, while Starowicz and Zielinski [5] analyzed the potential of Artificial Intelligence in acoustic design.

The findings suggest that although partial approaches exist, fully interoperable tools between BIM and acoustic analysis software are still lacking. A major obstacle is the absence of a structured acoustic ontology within the IFC standard [6], which hinders the full integration of acoustic analysis into BIM models.

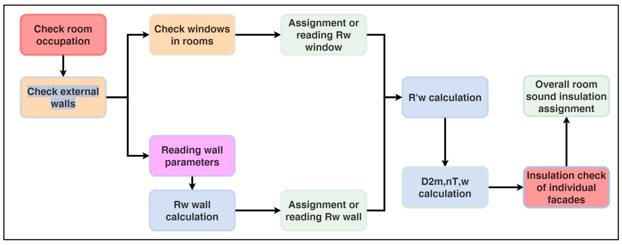

Figure 1. Rhino.Inside Grasshopper workflow.

2.1 Airborne sound insulation against outdoor noise

The workflow has been developed to calculate the standardised level difference of the façades of the occupied rooms $D_{2m,nT,w}$ as:

$$D_{2m,nT,w} = R'_w + \Delta L_{fs} + 10 \log \left(\frac{C_{sab} V}{T_0 S} \right) \qquad (1)$$

where:

- R'_w is the apparent sound reduction index of the façade;
- ΔL_{fs} is the level difference due to façade shape, in dB;
- C_{sab} is the Sabine constant, $C_{sab} = 0.16$ s/m;
- V is the volume of the receiving room, in m^3;
- S is the total area of the façade as seen from the inside, the sum of the area of all the façade elements, in m^2;
- T_0 is the reference reverberation time, $T_0 = 0.5$ s.

The volume and surfaces can be derived from the model, while ΔL_{fs} must be manually defined for each façade, as specified in Table C.1 (EN ISO 12354-3, Annex C).

The apparent sound reduction index R'_w of the façade is the sum of the sound reduction index R_w of the façade and a contribution due to the flanking transmissions of the surrounding elements. This contribution usually is negligible; however, if rigid components, such as concrete or brick, are connected to other rigid elements within the receiving room, such as floors or partition walls, flanking transmission can contribute to the overall sound transmission; so, in cases with rigid elements, flanking transmission can be incorporated globally by reducing the sound reduction index subtracting 2 dB (EN ISO 12354-3).

The sound reduction index of the façade, then, is the average of the sound reduction indexes of the elements composing it, mainly walls and windows, because it's possible to have different distributions of windows, with different areas and sound reduction indexes, in the façades, it's convenient, in the implemented workflow, to calculate an average sound reduction index and a total area of the windows of the single façade.

2.2 Model geometry

It has been considered, as a case study, a typical 4-floor office building constructed with a concrete structure and brick walls (Figure 2), featuring an additional external layer of high-density insulating mineral wool. From each office room, it has been derived, thanks to Rhino.Inside components, all the geometric inputs needed for the analysis, in particular:

- the volume $[m^3]$ of each room;
- the surface $[m^2]$ of each external wall;
- the dimensions $[m]$ of each window in the external walls of the considered rooms;
- the thickness $[m]$ of the layers of the wall stratigraphy.

2.3 Acoustic parameters

Due to the insufficient implementation of acoustic ontology in the IFC schema, it has been necessary to define some shared parameters in the Revit project to correctly insert acoustic parameters into the model, which can be queried for analysis, updated, or compiled at the end.

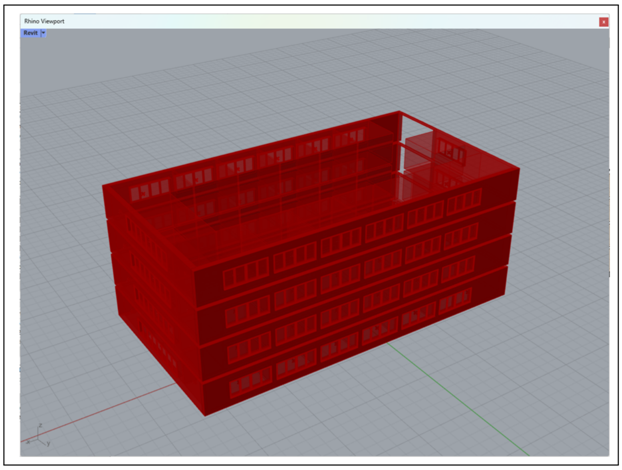

Figure 2. BIM model analysed.

This shared parameters could be of two different types:

- Type parameters, which define common properties shared by all instances of a specific type;
- Instance parameters, which represent unique properties of individual occurrences.

2.3.1 Input parameters

As input parameters, it is necessary to define the **Sound Reduction Index** of the elements involved, specified as a type parameter, because it is derived solely from the stratigraphy or the specific construction type of the element. In particular, while the sound reduction index of the windows is usually derived from facility testing and certified due to the standardised way they are produced, for the walls, it could be defined from facility testing in very specific conditions or, more often, derived from semiempirical formulas, like the ones suggested in the EN ISO 12354-1, where it's also defined how to calculate the ΔR_w due to additional layers, like wall linings or thermal insulation systems. Other necessary parameters are mainly instance parameters because they are specific for each element, like the **Occupancy** of each room, the **Façade Shape Factor**, potentially different for each external wall, or the **Flanking**, defined by the type of connections between external and internal walls.

2.3.2 Output parameters

As output parameters, it has been necessary to define a Sound Insulation parameter for each room into which to insert the calculation results and permit the automatic validation of the model according to EIR specifications in the IDS file.

Table 1. Input parameters.

Parameter	Typology	Data type
Sound Reduction Index	Type	integer
Façade Shape Factor	Instance	integer
Flanking	Instance	boolean
Occupancy	Instance	text

Table 2. Output parameters.

Parameter	Typology	Data type
Sound Reduction Index	Type	integer
Sound Insulation	Instance	integer

2.4 Outputs

Given the input parameters, the workflow calculates the standardised level difference of the façades ($D_{2m,nT,w}$), with a graphic and intuitive preview of the results to highlight those that need improvement, by changing the Sound Reduction Index of the windows or defining a new typology that could be selected from a database and instantly update the model (Figure 3).

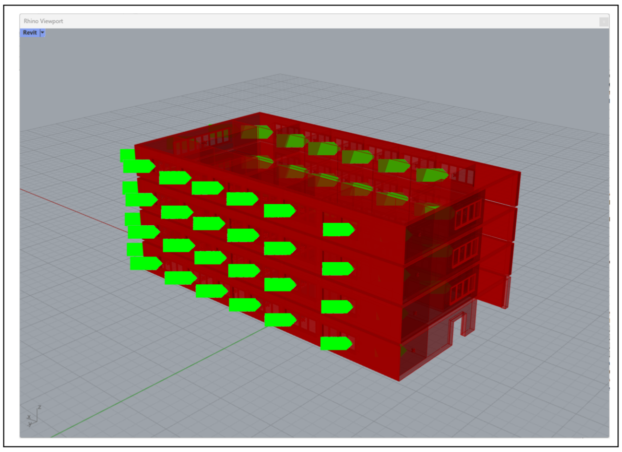

Figure 3. Façade insulation verified.

It is possible to export schedules or views from Revit with all the correct data directly in the right families and instances (Figure 4) and, defined the proper PSets according to EIR specifications, it is possible to export an IFC that can be validated with the IDS file.

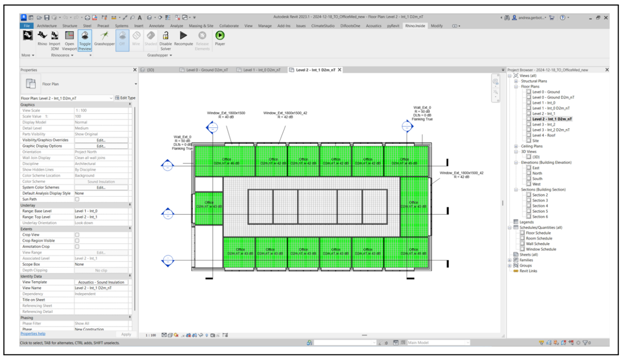

Figure 4. Floor plan with parameters.

3. CONCLUSIONS

This paper presented a novel workflow for integrating acoustic performance evaluation within a BIM-based multi-domain simulation framework. By leveraging Rhino.Inside Revit and Grasshopper, the approach ensures seamless interoperability between geometric and simulation tools, allowing for early-stage acoustic analysis alongside other performance criteria such as energy and daylighting. The proposed method enables the automated extraction of key geometrical and material parameters from BIM models, ensuring accurate and efficient façade sound insulation assessments.

The results demonstrate that incorporating acoustic analysis within the BIM workflow enhances decision-making by providing designers with immediate feedback on the acoustic performance of façade elements. The automated parameter integration and visualization capabilities further facilitate optimization, reducing manual errors and improving efficiency in the early design phase.

Some limitations remain. Certain parameters, such as the façade shape factor and flanking transmission contributions, still require manual input, which may introduce variability and reduce automation. Additionally, the Sound Reduction Index for walls often needs to be calculated externally using different theoretical models better suited to specific conditions, limiting full automation in material property assignment.

Future developments will focus on expanding the workflow to include more advanced room acoustics simulations and improving the implementation of curtain walls, given their widespread use in both new buildings and renovations, particularly in office and multifunctional spaces.

4. ACKNOWLEDGMENTS

The experimental activities presented in this paper were carried out as part of the H2020 project "iclimabuilt—Functional and advanced insulating and energy harvesting/storage materials across climate adaptive building envelopes" (Grant Agreement no. 952886).

5. REFERENCES

[1] L. Shtrepi, F. Aletta, L. Aspöck, A. Astolfi, J. Fels, M. Hornikx, K. Jambrošić, C.-H. Jeong, E. Kahle, J. Llorca-Bofí, J. H. Rindel, M. Rychtáriková, S. Torresin, and M. Vorländer, "Ten questions concerning Architectural Acoustics," *Building and Environment*, vol. 265, p. 112012, Nov. 2024.

[2] S. Kim, R. C. Coffeen, and P. Sanguinetti, "Interoperability Building Information Modeling and acoustical analysis software - A demonstration of a performing arts hall design process," *Proceedings of Meetings on Acoustics*, vol. 19, p. 015136, May 2013.

[3] C. C. Mastino, R. Baccoli, A. Frattolino, M. Marini, and C. Salaris, "Acoustic Insulation And Building Information Modeling: A Model Of Calculation For The Code Checking In The Forecast Phase And Of Measurement The Performances," *Proceedings of Building Simulation 2019: 16th Conference of IBPSA*, vol. 16, pp. 205–212, 2019.

[4] T. P. McGinley, T. Vestergaard, C.-H. Jeong, and F. Pind, "An OpenBIM workflow to support collaboration between Acoustic Engineers and Architects," *J. Phys.: Conf. Ser.*, vol. 2069, p. 012164, Nov. 2021.

[5] A. Starowicz and M. Zieliński, "Sustainable Acoustics: The Impact of AI on Acoustics Design and Noise Management," *ts*, Oct. 2024.

[6] D. Utkucu and R. Sacks, "Generation of acoustic ontology for a holistic building performance domain," *Proceedings of the 2023 European Conference on Computing in Construction and the 40th International CIB W78 Conference*, vol. 4, 2023.