Unified BIM-based simulation abstraction process

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Abstract. Interoperability between BIM environments and discipline-specific simulation tools remains limited in practice. Each engineering specialist relies on dedicated software with proprietary data models, geometric representations, and file formats that are rarely directly compatible. Therefore, engineers must manually translate BIM models into idealized representations suited to each analysis. This paper proposes a BIM-to-simulation (BIM2SIM) workflow based on controlled idealization. A Python script, named “Idealizer”, reads IFC geometry as well as metadata and exports discipline-specific lightweight formats for three simulation contexts applied to road noise barriers: outdoor acoustic analysis (Shapefile), structural assessment (DXF), and solar irradiation potential (CSV). The modular architecture makes the approach extensible to other infrastructure elements and engineering disciplines.

1. Introduction

Building Information Modeling (BIM) has significantly changed how infrastructure projects are designed and managed. By combining geometry, material properties, and semantic data in a single digital model, BIM improves coordination between project stakeholders and supports decision-making throughout the project lifecycle (Eastman, 2011). The IFC open standard (« Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries », 2024), was introduced to enable BIM data sharing between different software platforms.

However, a fundamental tension remains: most domain-specific simulation tools, like those for structural analysis, outdoor acoustic, solar irradiation and others, work with kernels either based on CAD or GIS platforms. They were developed and matured before IFC became widespread. Each specialist discipline therefore built its workflows around formats best suited to its own needs (DXF for structural analysis, Shapefile for GIS-based acoustics, CSV for georeferenced data). In the case IFC is adopted, import and export capacity varies considerably.

This gap forces engineers to perform a manual, repetitive, and discipline-dependent translation step: converting a rich BIM model into an idealized representation, stripped of unnecessary geometric details and adapted to the target tool's expected input. For infrastructure projects, where acoustic, structural, and solar analyses must be carried out in parallel on the same asset, this becomes a significant bottleneck.

This paper proposes an automated idealization approach. It is based on the hypothesis, that producing a simplified model specifically designed for a targeted simulation type and exported in a less complex format (like SHP, DXF or CSV) is more reliable than attempting to transfer a full IFC model. IFC might only be accepted by a limited number of simulation tools. When accepted, IFC classes covered for exchange vary from application to application.

Road noise barriers illustrate this challenge well. In a BIM model, a barrier is typically modelled as an assembly of panels, posts, and foundations. For outdoor acoustic simulation, only a georeferenced line representing the top edge is needed to build the corresponding model. For structural analysis, the engineer requires simplified surfaces and axis lines with material properties. Each discipline uses different software, different coordinate conventions, and different file formats.

The BIM2SIM workflow presented here is part of a broader project that also covers BIM-to-visualization (BIM2VIZ) and BIM-to-facility management (BIM2FM) transfers. These use cases share the same underlying principle: a central BIM model can be used as a common data source for multiple downstream applications, each requiring its own adapted representation.

2. Background and Related Work

2.1 BIM-to-simulation data exchange

Converting a BIM model into a structural analytical model requires not only geometric transformation but also significant manual corrections, and IFC data exchange between BIM and structural analysis software remains unreliable in practice (Ramaji et Memari, 2018).

Despite the existence of a dedicated IFC Model View Definition for structural analysis (Structural Analysis View), its practical adoption remains limited. As highlighted by Rudenko et Petryna, 2025, no certified software implementations are currently available, and significant inconsistencies have been observed in IFC data exchange between software claiming compliance. BIM models represent physical elements as volumetric solids, while structural analysis tools require simplified representations such as beam axes and surface elements. This transformation requires interpretation and cannot be performed automatically without prior knowledge of the analysis intent .

For acoustic simulation, a conversion workflow combining BIM and GIS data for outdoor traffic noise mapping has shown that outdoor acoustic tools require GIS-format inputs rather than IFC (Deng, Cheng et Anumba, 2016). An automated open-source approach for converting IFC geometry to Shapefile format has also been developed, performing comparably to commercial tools (Zhu *et al.*, 2019). In the field of building energy simulation, semi-automated methods for generating energy models from BIM data have been proposed (Jansen *et al.*, 2021), and extended to cases where the BIM model contains incomplete data (Wang *et al.*, 2026). A fully automated workflow for tunnel engineering converting IFC models directly into finite element meshes has also been demonstrated (Ninic *et al.*, 2021).

Despite these contributions, a research gap remains: no published workflow addresses the simultaneous multi-discipline idealization of infrastructure elements from a single IFC source, targeting lightweight and reliably supported formats for each discipline rather than attempting universal IFC exchange.

2.2 Geometric idealization

Idealization is the process of reducing a detailed geometric model to a simpler representation suited to a specific analysis (Ramaji et Memari, 2018). In structural engineering, this typically means converting a solid model into surfaces, beam axes, or point masses. A consistent observation in literature is that this process is analysis-specific: different simulations require different geometric abstractions, different metadata, and different file formats (Jansen *et al.*, 2021; Rudenko et Petryna, 2025). There is no single simplified representation that works for all disciplines.

FEM-specific parameters can be stored directly in the IFC model using custom property sets, allowing automatic generation of finite element models at different levels of complexity (Rudenko et Petryna, 2025). This method is effective when the BIM model has been specifically prepared for analysis. The approach presented in this paper differs in that it works with standard

BIM models produced in normal design workflows, without requiring any additional preparation.

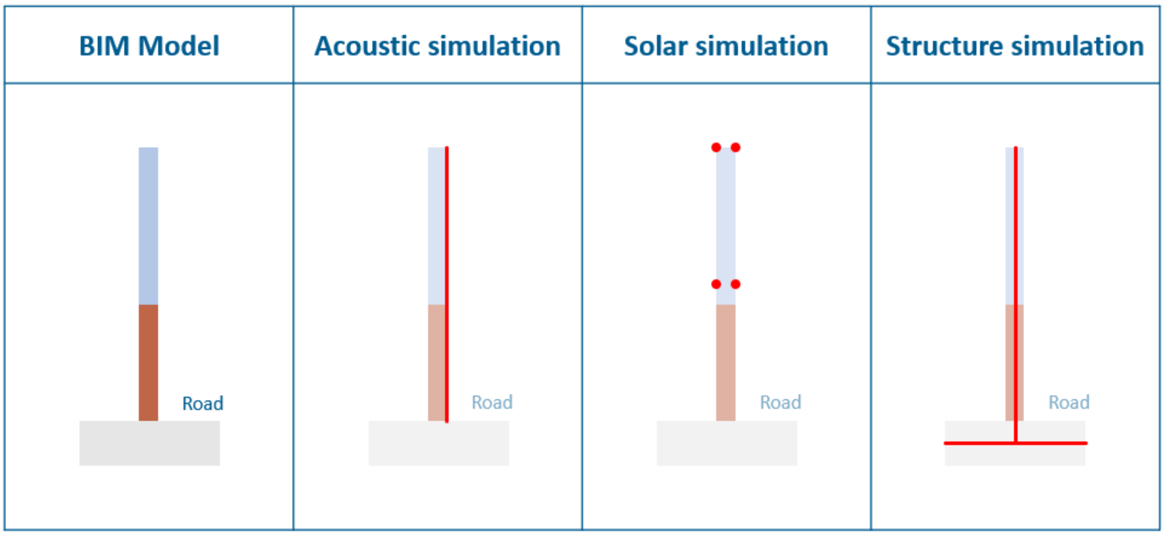

Figure 1. Idealization examples: from a detailed BIM model to discipline-specific simplified representations.

2.3 Format selection for simulation exchange

Data exchange between BIM and simulation tools can follow four main strategies: direct links between specific software products (proprietary and version-dependent); exchange via rich open formats such as IFC (offering broad coverage but with variable implementation quality); or exchange via established lightweight formats such as DXF, SHP, or CSV (with limited information content but reliable interpretation by most tools).

A fourth category consists of domain-specific exchange formats and dedicated add-ins, such as the Structural Analysis Format (SAF), an open standard supporting interoperability between BIM and structural analysis software (*Structural Analysis Format (SAF) – Specification*, 2022).

The structural analysis software market illustrates the limitations of IFC-based exchange. DXF and DWG are supported by all structural tools, while IFC support, though widely declared, varies considerably in quality. A frequent source of confusion is the existence of two IFC views both named with the word 'structural': the Coordination View represents physical volumes; the Structural Analysis View represents elements as axes and surfaces. These two views are not interchangeable, and most BIM tools export the former while most analysis tools expect the latter (Ramaji et Memari, 2018).

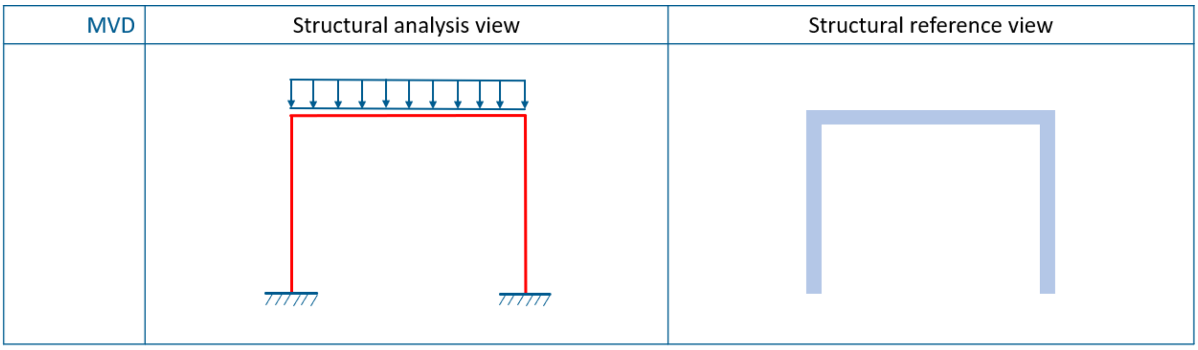

Figure 2. MVD differences: Structural Analysis View (axes and surfaces) vs Coordination View (physical volumes).

For outdoor acoustic simulation, the dominant tools in Switzerland (CadnaA, SLIP) are built on GIS platforms and use Shapefile as their primary geometry format.

An internal software survey showed that IFC is not a simulation-ready format, as it is either unsupported or requires transformation into discipline-specific representations, which directly drives the selection of output formats in the proposed workflow.

3. Methodology

3.1 Overall workflow

The proposed workflow is built around a central BIM model that serves as the common data source for all analyses. Discipline-specific models are derived from this central model through automated transformation. Changes to the BIM model are reflected in all analytical models when the process is re-run.

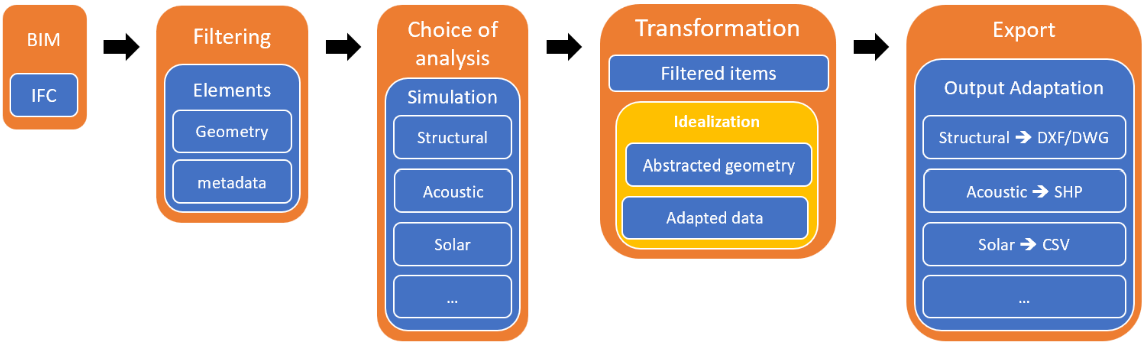

Figure 3. Overall BIM2SIM workflow from a central IFC model.

3.2 Software survey: geometry import formats

Before defining the idealization outputs, a survey of simulation software was carried out to identify which geometry formats are supported and reliably interpreted for tools of each category.

Structural analysis software

Twenty structural analysis packages were reviewed (including SCIA Engineer, RFEM, SOFiSTiK, etc.) DXF and DWG are supported by all twenty tools. IFC is present in fourteen, but the quality of geometry interpretation varies considerably, and enabling a structural analysis still requires the engineer to idealise the geometry manually.

Outdoor acoustic simulation software

Outdoor and indoor acoustic simulation tools use fundamentally different calculation methods and data formats. Indoor tools sometimes support IFC, but outdoor propagation software is built around GIS data. In Switzerland, the main tools used for road noise studies (CadnaA and SLIP) work with Shapefile (SHP) as their primary geometry format, consistent with the ISO 9613 method (International Organization for Standardization, 1993).

Solar irradiation analysis

Solar potential analysis can be performed natively in ArcGIS Pro using the Solar Radiation toolset, which is part of the Spatial Analyst extension and accepts georeferenced point or polygon features as direct input. In QGIS, equivalent functionality requires a plugin such as UMEP/SEBE or the r.sun function from GRASS GIS. While IFC import is technically possible through some environments such as Rhino with the Ladybug plugin, the geometric preprocessing required adds complexity and risk. A CSV file of georeferenced points with azimuth and north orientation attributes is sufficient for solar radiation calculations and can be read directly by the tools mentioned above.

3.3 Format selection

Table 1 summarises the format selected for each analysis type.

Analysis	Ecosystem	IFC exchange quality	Add-ins / proprietary	Selected format
Acoustic (outdoor)	GIS	Not supported	Not relevant	SHP (Shapefile)
Structural analysis	CAD / FEM	Present but variable	Existing (e.g. SAF)	DXF
Solar / PV potential	GIS	Possible but complex	ArcGIS Pro / QGIS	CSV (georef. points)

Table 1. Format selection per analysis type based on software survey.

4. Implementation: "Idealizer"

4.1 Overview

The "Idealizer" is a Python script executed within the Blender / BlenderBIM environment. It relies on the Bonsai library to access IFC geometry and property sets (Psets) through a Python API. The script is structured into three independent modules, each corresponding to a specific analysis type. A shared processing layer ensures coordinate transformation to the Swiss national reference system (MN95), guaranteeing spatial consistency across all outputs.

Figure 4 illustrates the overall idealization workflow, while Figure 5 presents the reference noise barrier BIM model in Blender.

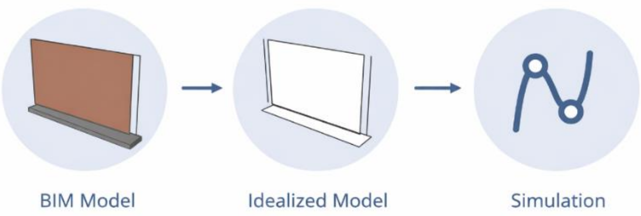

Figure 4. Idealizer principle: one IFC source, three discipline-specific outputs.

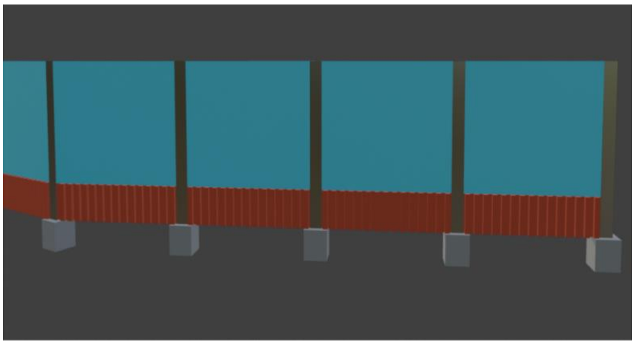

Figure 5. Reference noise barrier BIM model loaded in Blender/BlenderBIM.

4.2 Acoustic idealization module

For outdoor acoustic simulation, noise barriers are represented as georeferenced polylines that trace the top edge of the structure. This top edge is the main diffraction point used in ISO 9613-based calculations. The full height of the barrier is not included in the geometry: acoustic tools reconstruct the barrier surface automatically by projecting the top edge downward onto the Digital Terrain Model.

The acoustic module extracts the top vertices of the IfcColumn elements, orders them along the barrier axis, and builds a continuous polyline. Acoustic absorption coefficients stored as face-level properties in the IFC Psets are added to the polyline as attributes. The geometry is then converted to MN95 coordinates and exported as a Shapefile (Figure 6).

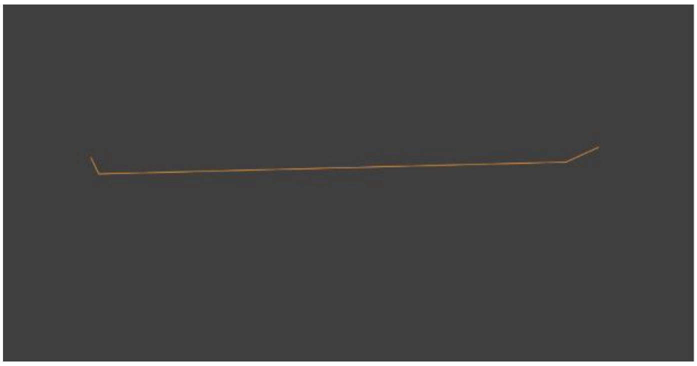

Figure 6. Acoustic idealization: georeferenced upper-edge polyline exported in SHP format (Blender view).

4.3 Structural idealization module

For structural analysis, the module produces three types of elements: cross-section profiles for the foundation elements, centreline axes for the columns, and surface elements for the barrier panels. These are extracted from the IfcColumn, IfcWall and IfcFooting elements and exported as DXF entities.

Material properties from the IFC model are not included in the DXF output at this stage. The geometry provides a geometric framework for the structural engineer to build the analytical model in their preferred software. A planned extension is to retain MN95 coordinates in the output, which would allow spatially variable loads (wind, snow, seism) to be assigned based on the barrier location. Figures 7 and 8 show the idealised model in Blender and the result in SCIA Engineer.

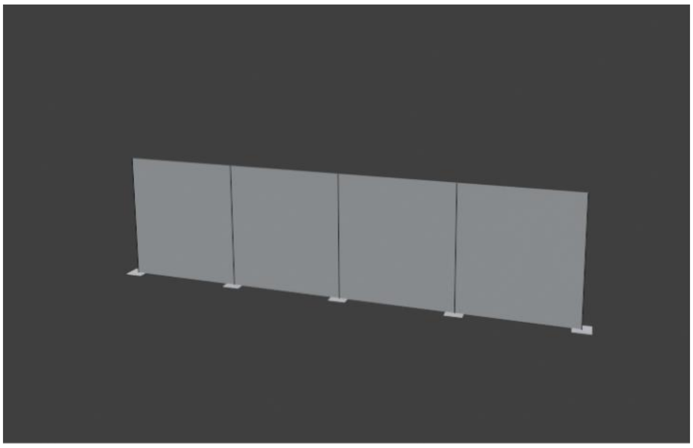

Figure 7. Structural idealization: simplified surface derived from the IFC model (Blender view).

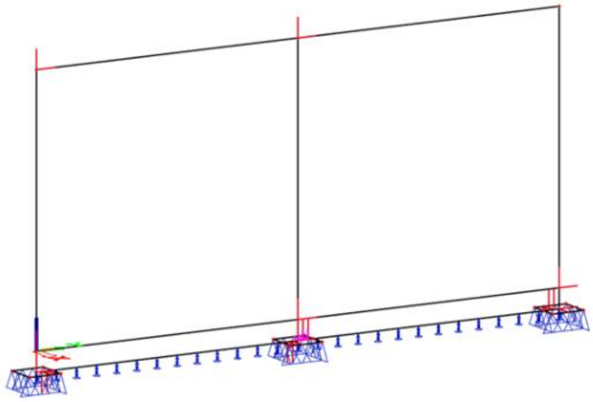

Figure 8. Idealization geometry imported in SCIA Engineer.

4.4 Solar irradiation module

For photovoltaic potential analysis, the module generates georeferenced points based on a geometric analysis of post elements. For each post, its main orientation is derived from the bounding box to identify front and back faces, from which points are extracted at three elevation levels (top, mid, bottom). Additional central points are computed between adjacent posts to represent panel surfaces. The normal vectors at these locations are then used to calculate slope and azimuth, corrected according to the true north orientation in MN95, and the results are exported as a CSV file readable by ArcGIS Pro (Figure 9).

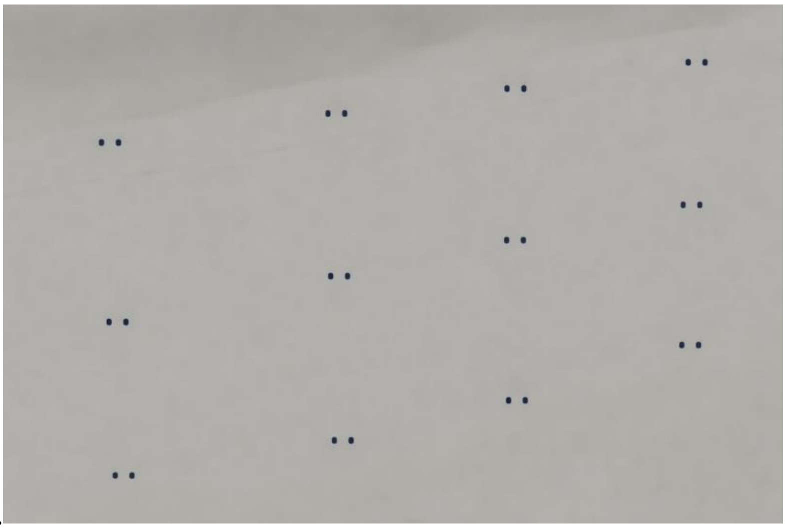

Figure 9. Idealization points imported in ArcGIS Pro.

5. Results and Discussion

5.1 Summary of outputs

Table 2 summarises the outputs produced by the Idealizer for each analysis type.

Analysis	Idealised geometry	Format	Target tool
Acoustic (outdoor)	Georef. upper-edge polyline + absorption attributes	SHP	CadnaA / SLIP
Structural analysis	Axis lines, cross-sections, surface elements	DXF	SCIA Engineer
Solar / PV potential	Georef. points with azimuth + north orientation	CSV	ArcGIS Pro

Table 2. Idealizer outputs per analysis type.

5.2 Strengths of the approach

Using the same BIM model as the source for all three analyses ensures that the acoustic, structural, and solar models are consistent with each other. In a conventional workflow, each specialist produces his own simplified model independently, which increases the risk of inconsistencies. The Idealizer applies the same transformation rules to the same IFC source each time, removing this risk.

Targeting lightweight formats rather than IFC also improves reliability. DXF is supported by all structural tools in the survey, SHP is the native format for outdoor acoustic software, and CSV requires no specialised importer. Each format is chosen because it is well understood by the target tools, which reduces the risk of incorrect interpretation.

5.3 Limitations and current scope

The current algorithm does not handle composite or geometrically complex barriers. When a barrier combines elements with varying heights, materials, or geometries, multiple valid idealizations can be defined rather than a single correct one. As structural complexity increases, so does the risk of misinterpretation during model simplification. The appropriate representation therefore depends on the target simulation software, the required level of detail, and the surrounding environment in the acoustic model. An overly detailed idealization may lead to unnecessary computational costs, while an overly simplified one can reduce the accuracy of the results.

For the structural module, material properties from the IFC model are not yet included in the DXF output. For the solar module, outputs are currently limited to ArcGIS Pro. All three modules work with standard barrier elements as defined by the Swiss TRACE manual (ASTRA, 2024). Extending the approach to other infrastructure element types would require new IFC parsing rules for each element.

5.4 Discussion

The approach presented in this paper is based on the observation that transmitting less information more reliably is preferable to transmitting more information with uncertain results. When a rich IFC model is imported by a simulation tool, errors in geometry interpretation may not be visible to the user. A simpler format that the tool can read correctly avoids this risk. The software survey results support this choice: DXF, SHP, and CSV are consistently supported across all tools tested, while IFC exchange quality varies significantly depending on the software version and the IFC view used.

6. Conclusion

This paper presented a BIM-to-simulation workflow based on geometric idealization, applied to road noise barriers. The Idealizer, a Python script with three independent modules, automatically produces discipline-specific analytical models from a single IFC source model and exports them in formats that are reliably supported by the target simulation tools.

The workflow was tested for three types of simulation: outdoor acoustic analysis, structural assessment, and solar potential analysis. A survey of simulation software showed that lightweight formats (DXF, SHP, CSV) offer more consistent support than IFC across the tools used in practice, and this finding guided the format choices made in the workflow.

The modular structure of the Idealizer makes it straightforward to add new modules for other analysis types or infrastructure elements. Future work will focus on handling composite and geometrically complex barriers, adding material metadata to the structural output, adding material properties and georeferenced coordinates to enable automatic assignment of spatially variable loads, and extending the solar module to additional tools.

Several directions could extend this work. The most immediate priority is to improve the idealization algorithm to handle composite and geometrically complex barriers, which would require encoding discipline-specific rules in collaboration with acoustic and structural specialists. A second direction concerns the structural module: adding material properties and georeferenced coordinates to the DXF output would allow structural engineers to assign spatially variable loads (wind, snow, seismic) automatically based on barrier location, reducing the manual steps still required after idealization.

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