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IFC OPEN BIM FOR NOISE EMISSION EVALUATION OF THE HVAC SYSTEMS

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ABSTRACT

The European Community has introduced several directives and initiatives to promote the digitalization of buildings, aiming to improve enviromental efficiency and reduce carbon emissions. The obligation of BIM (Building Information Modeling) in Europe is regulated by Directive 2014/24/EU on public procurement, which promotes the use of BIM to improve efficiency and transparency in public projects. In several European countries the law require the use of open and interoperable formats, such as IFC (Industry Foundation Classes), to ensure of read the data for many years. The evaluation of noise emitted by HVAC (Heating, Ventilation, and Air Conditioning) systems using BIM models in open IFC format represents an innovative and precise approach. BIM models allow the integration of acoustic data directly into the project, facilitating noise analysis at different stages. The use of the IFC format ensures interoperability between different software, enhancing collaboration among professionals. This approach helps identify and mitigate noise sources, optimizing the acoustic comfort of buildings and complying with current regulations. In summary, the integration of IFC-BIM in HVAC noise evaluation offers an efficient and collaborative solution. This work analyzes all the information managed by the IFC format on HVAC system noise emission, highlighting deficiencies and proposing improvements.

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1. INTRODUCTION

Building Information Modeling (BIM) for buildings, and particularly Mechanical, Electrical, and Plumbing (MEP) is a methodology that enables the design, management, and maintenance of a building's technical systems in an integrated and collaborative manner. At the European level, the adoption of BIM is regulated by various standards, including in Italy the BIM Decree (DM 560/2017) and its subsequent amendments, which make the use of BIM mandatory for public works above a certain amount. The Ministerial Decree 560/2017, known as the BIM Decree, establishes the methods and timelines for the progressive introduction of electronic modeling methods and tools for construction and infra-structure in Italy. The obligation to adopt BIM in public procurement was introduced gradually from 2019 to 2025. The decree also defines EIR (Employer's Information Requirements), known in Italy as "Capitolato informativo", interoperable platforms, and open formats. The main objective is to improve the efficiency, transparency, and quality of public construction projects. The latest Public Procurement Code, updated with Legis-lative Decree 36/2023, confirms the obligation to use BIM for a wide range of public projects starting from 2025. This obligation applies to new construction projects and interventions on existing buildings with an estimated project value exceeding 2 million euros, and for cultural heritage with a threshold of 5.538 million euros. The code also provides technical incentives for the use of BIM procedures and promotes the adoption of interoperable platforms and open formats such as IFC and OpenBIM. The goal is to improve the efficiency, transparency, and quality of public construction projects. **Figure 1** provides an overview of the regulations and strategies adopted by various European countries for the adoption of BIM procedures at the governmental level. Among the most active nations on this issue is Lithuania, where the obligation to use Building Information Modeling (BIM) methods was established starting from January 1, 2021. This obligation applies to high-value construction projects in the public sector, with the aim of improving efficiency and resource management.

Figure 1. Countries of the European Community

In Lithuania, the adoption of BIM is promoted through various initiatives and regulations. The Lithuanian government has recognized the importance of BIM to improve the efficiency and quality of construction projects. In 2018, the Ministry of Environment introduced guidelines for the implementation of BIM in public projects, encouraging the use of this methodology for all new construction projects funded with public funds. Additionally, Lithuania follows international and Europe-an standards, such as the ISO 19650 series[1–6], which provides a framework for managing information related to construction and civil engineering works using BIM. These standards help ensure interoperability and consistency of information among the various stakeholders involved in projects. The adoption of BIM in Lithuania is seen as a crucial step to modernize the construction sector, improve transparency, and reduce project costs and completion times. Other non-European Union countries have also contributed to the development of BIM. The United Kingdom has been one of the pioneers in adopting BIM. The main regulation is PAS 1192, which has been replaced by international standards ISO 19650. Since 2016, the use of BIM has been mandatory for all public projects, with the goal of achieving BIM Level 2 maturity. The "Digital Built Britain" program aims to bring the construction sector to BIM Level 3 maturity by 2025. In Singapore [7,8], the government actively promotes the use of Building Information Modeling (BIM) in the construction sector. Since July 1, 2015, all projects with a gross floor area of 5,000 m² or more must be submitted in BIM format. The Singapore BIM Guide provides detailed guidelines for BIM implementation [9], covering modeling and collaboration specifications and procedures. Additionally, the country has introduced Integrated Digital Delivery (IDD) to integrate digital technologies throughout the construction lifecycle. In the United States, BIM is widely used, with mandates for public projects in many states. In Canada, BIM is rapidly gaining ground, with national standards under development. The United Arab Emirates has adopted BIM to improve efficiency in their ambitious construction projects. In Australia, BIM is used for infrastructure and building projects, with national guidelines pro-moting its adoption. In China [10] and Japan [10,11], BIM is also widely adopted to im-prove efficiency and quality in construction projects. An open and interoperable BIM format is essential to ensure collaboration among the various project stakeholders. The Industry Foundation Classes (IFC) format [12,13], standardized by buildingSMART In-ternational, is one of the most widely used for interoperability between different software platforms. IFC allows data exchange between different BIM platforms, ensuring that all information is accessible and usable by all project participants.

2. DATA STRUCTURE IN THE IFC FORMAT FOR HVAC SYSTEMS

The authors can submit for the EAA FA2025 Conference either a short paper from 2 to 4 pages or a long paper of maximum 8 pages, all written in English, and not previously published. Each length indicated is intended as overall and includes figures, tables, references and acknowledgments.

The Industry Foundation Classes (IFC) format is an open standard for data representation in Building Information Modeling (BIM), which facilitates interoperability between different software applications in the construction sector. Within IFC, HVAC (Heating, Ventilation, and Air Conditioning) systems are represented through a series of specific entities that describe components and equipment used for environmental control in buildings. HVAC entities in the IFC format are included in the IfcHvacDomain subschema, which defines the fundamental concepts for interoperability in the HVAC domain. This schema includes entities that represent both the segments and fittings of distribution systems (such as ducts and pipes) and the equipment typically used in building services, such as boilers, chillers, fans, and pumps. It also considers vibration isolation associated with these components. Examples of HVAC entities in the IFC format include:

- IfcAirTerminal: represents air terminals such as diffusers or grilles.
- IfcBoiler: represents a boiler used for heating.
- IfcChiller: represents a chiller for cooling water.
- IfcFan: represents a fan used for air movement.
- IfcPump: represents a pump for fluid circulation.

These entities can have detailed properties such as location, dimensions, manufacturer, operational status, and other relevant parameters. Managing acoustic properties in the IFC format is essential for evaluating and controlling the sound performance of buildings. One of the main properties used is AcousticRating, which indicates the sound transmission resistance of a given object through a standardized index. This property is often specified according to national building codes and provides an indicative value of the element's acoustic insulation capacity. AcousticRating can be applied to various entities in the IFC format, including:

- IfcWall: to evaluate the acoustic insulation of walls.
- IfcSlab: to determine the acoustic performance of slabs.
- IfcDoor: to analyze sound transmission through doors.
- IfcWindow: to evaluate the acoustic insulation of windows.

Integrating these acoustic variables into the BIM model allows professionals to simulate and analyze the acoustic performance of buildings during the design and subsequent phases, helping to ensure acoustic comfort and compliance with current regulations. Additionally, the use of open standards like IFC facilitates the integration of acoustic information with other aspects of building design, promoting a holistic and multidisciplinary approach in the design and construction process. In the Figure 2 is show the entity in IFC space

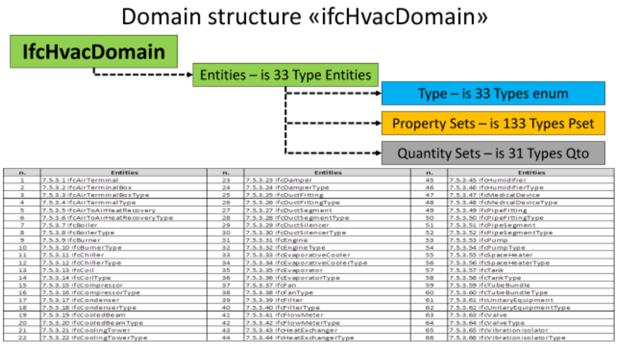

Figure 2. Entity into IFC format

3. DATA FLOW FOR DESIGN AND CHECK WITH THE PHONOMETER

The workflow with Building Information Modeling (BIM) tools for acoustic design and instrumental noise verification allows for an integrated and multidisciplinary approach to designing acoustic comfort in buildings. The process develops in several stages, each supported by interconnected digital tools. Figure 3 shows the workflow from the initial modeling phase to the verification of results. The initial phase involves the architectural modeling of the building in BIM software such as Revit, Archicad, or Allplan, where building elements (walls, floors, fixtures) and systems (HVAC, water, electrical) are inserted. BIM objects must be equipped with relevant acoustic properties, such as Rw (sound insulation index), Ln,w (impact noise), DnT,w (apparent sound insulation), and surface mass. These properties can be added manually or imported from standardized digital dictionaries like the bSDD (buildingSMART Data Dictionary) [14] or manufacturer databases. Subsequently, the model is exported in IFC format to be analyzed with acoustic simulation software such as CATT-Acoustic, Odeon, Insul, or SoundPLAN, GEAR [15]. These tools allow for the simulation of sound propagation in indoor environments and insulation between rooms, considering materials, geometries, volumes, and sound sources. At this stage, the project can be optimized, for example, by modifying stratifications, adding suspended ceilings, sound-absorbing panels, or acoustic barriers. After construction, in-situ instrumental verification is carried out by competent technicians with sound level meters and standardized sound sources. The detected data (such as sound pressure levels, reverberation times, or insulation indices) are compared with the design values. The results can be inserted into the BIM model through parametric properties, creating an acoustic as-built. Finally, all documentation (technical reports, graphs, measurements) can be attached to the BIM model as informational objects, making the project consultable, traceable, and updatable over time. This workflow allows for the design of buildings compliant with regulations (such as UNI 11367 [16] or ISO 12354 [17–22]), improves the quality of acoustic comfort, and reduces the risk of disputes.

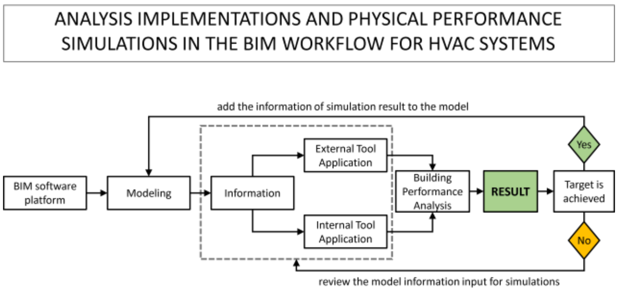

Figure 3. Entity in to IFC format

The IFC data structure does not contain all the necessary information for acoustic calculation. The default property sets contain only a few very limited parameters. To address this, it is necessary to define a bSDD [14] at the standard level for acoustic calculation and verification, within which all the variables present in the various technical standards used are included. Figure 4 shows the workflow that can be followed in the modeling phase and in the code checking phase for the verification of acoustic parameters

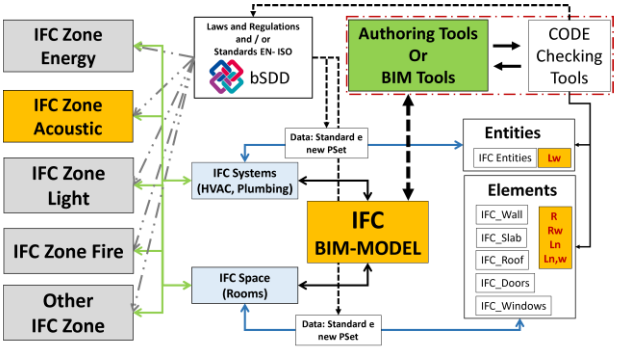

Figure 4. Entity in to IFC format

4. CONCLUSION

In conclusion, the integration between BIM modeling and acoustic design represents a significant breakthrough for the construction sector. The use of digital tools allows for a more precise, coordinated, and informed approach, capable of improving both design quality and environmental comfort. The interoperability between software, data traceability, and the ability to anticipate acoustic issues from the early stages of the project provide tangible benefits for designers, companies, and clients. The synergy between technologies and skills promotes a holistic vision of the building, where sound is considered an integral part of well-being. Investing in acoustic design through BIM is not only a technical choice but also a cultural and sustainable one. In a context increasingly focused on quality of life and energy efficiency, acoustic comfort becomes an essential requirement. Today, digitalization offers all the tools to achieve it effectively. It is up to us to use them to their fullest potential.

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6. REFERENCES

[1] ISO, 2018, “ISO 19650-1 - Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling (BIM) — Information Management Using Building Information modellingPart 1: Concepts and Principles.” [Online]. Available: 1.

[2] 2018, “ISO 19650-2 -Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling (BIM) — Information Management Using Building Information modellingPart 2: Delivery Phase of the Assets.”

[3] 2020, “ISO 19650-3 - Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling (BIM) — Information

Management Using Building Information modellingPart 3: Operational Phase of the Assets."

[4] 2022, "ISO 19650-4 - Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling (BIM) — Information Management Using Building Information modellingPart 4: Information Exchange."

[5] 2020, "ISO 19650-5 - Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling (BIM) — Information Management Using Building Information modellingPart 5: Security-Minded Approach to Information Management."

[6] 2025, "ISO 19650-6 - Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling (BIM) — Information Management Using Building Information modellingPart 6: Health and Safety Information."

[7] Liao, L., Teo, E. A. L., Chang, R., and Zhao, X., 2020, "Diffusion of Building Information Modeling in Building Projects and Firms in Singapore," Sustainability, **12**(18), p. 7762. https://doi.org/10.3390/su12187762.

[8] Liao, L., Teo, E. A. L., and Chang, R., 2019, "Reducing Critical Hindrances to Building Information Modeling Implementation: The Case of the Singapore Construction Industry," Applied Sciences, **9**(18), p. 3833. https://doi.org/10.3390/app9183833.

[9] 2013, "Singapore BIM Guide Version 2." [Online]. Available: https://www.corenet.gov.sg/media/586132/Singapore-BIM-Guide_V2.pdf.

[10] Liu, B., Wang, M., Zhang, Y., Liu, R., and Wang, A., 2017, "Review and Prospect of BIM Policy in China," IOP Conf. Ser.: Mater. Sci. Eng., **245**, p. 022021. https://doi.org/10.1088/1757-899X/245/2/022021.

[11] Rui, S., Makanae, K., Fujiu, M., and Morisaki, Y., 2024, "SWOT-AHP Analysis of BIM Technology Utilization in the Japanese Construction Industry," Buildings, **14**(11), p. 3549. https://doi.org/10.3390/buildings14113549.

[12] Mastino, C. C., Baccoli, R., Frattolillo, A., Marini, M., and Bella, A. D., "The Building Information Model and the IFC Standard: Analysis of the Characteristics Necessary for the Acoustic and Energy Simulation of Buildings," p. 8.

[13] 2018, "ISO 16739-1:2018 Industry Foundation Classes (IFC) for Data Sharing in the Construction and Facility Management Industries -- Part 1: Data Schema."

[14] BuildingSMART International, "buildingSMART Data Dictionary (bSDD) - Https://Www.Buildingsmart.Org/Users/Services/Buildingsmart-Data-Dictionary/." [Online]. Available: https://www.buildingsmart.org/users/services/buildingsmart-data-dictionary/.

[15] Marini, M., Baccoli, R., Mastino, C. C., Da Pos, V., and Tóth, Z., 2015, "A New Computational Model: G.E.A.R. Graphical Expert Analytical Relations," *Proceedings of BSA 2015, the Second IBPSA-Italy Conference on "Building Simulation Applications,"* bu,press - Bozen-Bolzano University Press Free University of Bozen-Bolzano, Bolzano, pp. 305–312. [Online]. Available: http://www.ibpsa.org/proceedings/BSA2015/9788860460745_38.pdf.

[16] 2010, "UNI 11367:2010 - Acoustics in buildings - Acoustic classification of residential units - Field evaluation and verification (in Italian)."

[17] 2017, "ISO 12354-1:2017 Building Acoustics -- Estimation of Acoustic Performance of Buildings from the Performance of Elements -- Part 1: Airborne Sound Insulation between Rooms."

[18] 2017, "ISO 12354-2:2017 Building Acoustics -- Estimation of Acoustic Performance of Buildings from the Performance of Elements -- Part 2: Impact Sound Insulation between Rooms."

[19] 2017, "ISO 12354-3:2017 Building Acoustics -- Estimation of Acoustic Performance of Buildings from the Performance of Elements -- Part 3: Airborne Sound Insulation against Outdoor Sound."

[20] 2017, "ISO 12354-4:2017 Building Acoustics -- Estimation of Acoustic Performance of Buildings from the Performance of Elements — Part 4: Transmission of Indoor Sound to the Outside."

[21] 2009, "EN 12354-5:2009 Building Acoustics - Estimation of Acoustic Performance of Building from the Performance of Elements - Part 5: Sounds Levels Due to the Service Equipment."

[22] 2003, "EN 12354-6:2003 Building Acoustics - Estimation of Acoustic Performance of Buildings from the Performance of Elements - Part 6: Sound Absorption in Enclosed Spaces."