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HVAC-INFORMED THERMAL ZONING FOR BIM2BEM TRANSFORMATION

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Abstract

Building Energy Modelling (BEM) extends performance evaluation beyond direct monitoring. Integrating BEM with Building Information Models (BIM), called BIM2BEM, streamlines energy performance analyses. However, strict one-to-one geometric correspondence often results in unnecessary complexity, inflating computational costs without significantly improving accuracy. This study proposes an HVAC-informed thermal zoning approach within a BIM2BEM workflow, integrating geometry processing, HVAC topology establishment, zoning scenario generation, and model simplification, thereby automating simplified BEM generation. Its effectiveness is demonstrated by applying it to a complex building. The results indicate that different zoning routines can minimise the risk of overestimating building energy requirements and oversizing HVAC systems.

Introduction

BIM2BEM has become an increasingly prominent topic in advancing building performance analysis, with recent developments introducing innovative methodologies to streamline the generation of simulation-ready models while addressing challenges in model transformation and data interoperability. These advancements leverage BIM's parametric design features and interoperability standards, enabling the efficient translation of complex architectural details into simplified forms suitable for energy simulation. Gao et al. (2019) reviewed automated BIM2BEM frameworks explored to enhance the data exchange, improving workflow efficiency and accuracy in sustainable building design applications. Despite some advancements in this field, achieving a fully automated and error-free BIM2BEM framework remains a significant challenge due to persistent issues with accuracy and data exchange, as reported by Kamel and Memari (2019). They indicated that addressing these challenges has involved reviews of existing tools and methodologies, highlighting EnergyPlus as a widely adopted energy simulation platform due to its versatility. Additionally, BIM-based energy modelling applications have been categorised by objectives such as performance prediction and operational management, identifying innovations and improvement opportunities, as reviewed by Pezeshki et al. (2019). These insights underscore the transformative potential of digital integration in sustainable building development while emphasising the need for ongoing refinement in automation and interoperability.

In terms of building geometry, generating the geometric content of a BEM model, particularly the second-level space boundary (2LSB) surface set of a building, is a critical and challenging task in the BIM2BEM process. Numerous algorithms have been proposed to address this complexity, including those developed by Ramaji et al. (2020) and Chen et al. (2023). To simplify this process and eliminate the need for manual 2LSB generation, the gbXML format was introduced by Dena et al. (2024). As a lightweight BIM data schema for describing building geometries, gbXML reduces the effort required to reconstruct building models. Another workflow combined gbXML (as the BIM input format) with EnergyPlus (as the simulation engine) proposed by Elnabawi (2020). In addition to gbXML, Industry Foundation Classes (IFC) is another commonly used data format in BIM2BEM workflows. Compared to gbXML, IFC provides more detailed descriptions of building data, making it particularly suitable for modelling architectural, mechanical, and electrical components. Lilis et al. (2017) proposed an IFC-based workflow to generate the 2LSB surface set for building energy performance simulation purposes. Ying and Lee (2019) introduced an algorithm to transform curved BIM geometries into polyhedral forms, ensuring geometric consistency and enhancing efficiency in architectural BEM generation. In the realm of geometric data handling, Lobos Calquín et al. (2024) proposed a framework for automated data exchange, facilitating the integration of proprietary BIM tools with national certification systems. Kim et al. (2015) tackled interoperability challenges by developing a Modelica library, enabling semi-automated BIM2BEM conversion through an API and yielding promising outcomes during early design stages. Additionally, Jeong et al. (2014) proposed a method for BIM2BEM translation using Modelica, supporting seamless model conversion for thermal simulations and system optimisation.

Beyond mapping building geometric information within BIM2BEM, researchers have also explored strategies to optimise zoning approaches for thermal simulations.

These methods focus on automatically and intelligently aggregating spaces from BIM models into thermal zones, significantly reducing computational costs while maintaining the accuracy of building energy simulations, as reported by Shin and Haberl (2019). By integrating automated zoning with BIM2BEM workflows, these approaches aim to strike a balance between simulation efficiency and model fidelity. Wu et al. (2023) introduced an ontology-based framework with thermal zoning that consolidates multiple data sources to create BEM models in the EnergyPlus environment, significantly reducing modelling time. Lilis et al. (2019) proposed an algorithmic process to simplify 2nd-level space boundary surface set, reducing surface complexity and computational effort in building performance simulation models. Addressing the limitations of treating each space as a thermal zone enhances efficiency without sacrificing accuracy. Georgescu and Mezić (2015) introduced a systematic approach using the Koopman operator to decompose building geometric data into different spatial modes, creating simplified models with varying granularity to analyse the impact of zoning strategies.

While previous studies have made progress in thermal zoning, they primarily focus on geometric aspects and room functions, lacking an effective and seamless integration of HVAC information within a BIM2BEM framework. This gap would limit the accuracy and practicality of thermal zoning in real-world building performance simulations. To address the challenges within this domain, this study proposes an HVAC-informed thermal zoning approach for model simplification within a seamless and automated BIM2BEM workflow, considering both HVAC information and building geometric data. The proposed workflow was applied to a complex building with intricate HVAC systems to demonstrate its efficacy and feasibility. Based on the HVAC topology, multiple zoning scenarios were generated and subsequently assessed for their influence on the outcomes of building performance simulations. The findings highlight how HVAC-informed thermal zoning can affect simulation accuracy and underscore its potential to enhance the flexibility of BIM2BEM workflows.

Methodology

The methodology of this work is divided into three stages, as shown in Figure 1, detailed in the following subsections. In Step (A), a BEM model with complete geometric information is transformed from the input BIM data using a geometry-based BIM2BEM workflow. The thermal zones in the BEM correspond to the physical spaces of the building, as defined by its construction elements (e.g. walls and floors). In Step (B), a knowledge graph-based HVAC topology is established semi-automatically based on the input BIM data and a geometric relation-checking process. Considering intra- and inter-floor constraints, a series of HVAC topology-driven zoning scenarios are produced to group IfcSpaces in BIM to thermal zones in BEM according to their IFC Global Unique Identifiers (GUIDs). In Step (C), the simplification tool (SMT) Lilis et al. (2019) is utilized to merge the grouped spaces into thermal zones and convert the corresponding second-level space boundaries into second-level zone boundaries. This process automatically generates simplified (post-zoning) BEM models with complete and accurate geometric information. These models are then enriched with openings, thermal internal gains, and HVAC configurations derived from the HVAC topology. As a result, fully simulation-ready BEM models are obtained for batch simulation to analyse the impact of thermal zoning strategies on energy demands.

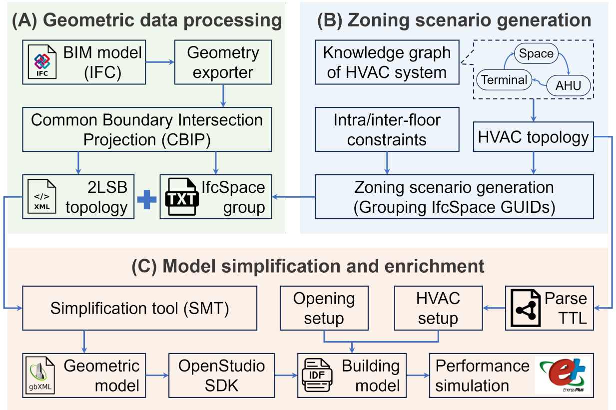

Figure 1: Framework and methodology of this work.

A. Geometric data processing

The first processing stage of the introduced methodology consists of three processing steps: extracting BIM geometry with the Geometry Exporter tool (A1), generating BEM geometry (2LSB surface set) using the Common Boundary Intersection Projection (CBIP) process (A2), and exporting the BEM geometric data to a gbXML file format through an Extract-Transform-Load (ETL) tool (A3). These steps are displayed in block A of Figure 1, and analysed next.

A1. BIM geometry extraction

In this step, geometric data from the input BIM IFC file is extracted using the Geometry Exporter tool, which forms part of the online tool suite detailed in Katsigarakis et al. (2021). The extracted data includes three-dimensional solid representations of the building's spaces and openings (if the latter exists). These representations are defined as boundary representations, adhering to the outward normal rule, where the normal vectors of the boundary surfaces point outward from the volume of the space or opening. The resulting boundary representations are exported in an XML file for subsequent processing.

A2. BEM geometry generation

To generate the geometric content required for BEM, a simplified version of the Common Boundary Intersection Projection (CBIP) process, as proposed by the previous work in Lilis et al. (2017), is applied to the geometric BIM data extracted in Step A1. This process produces polygonal surfaces, called second-level space boundaries (2LSBs), which define the interfaces through which thermal exchanges occur between adjacent building spaces and the external environment, such as outdoor air or ground. The resulting geometric definitions are structured into an XML file, known as the 2LSB surface set. As illustrated in Figure 2, the CBIP process processes three spatial volumes, generating internal 2LSB surface pairs (represented as dashed lines) and external 2LSB surfaces (represented as solid lines), providing a detailed and accurate representation of thermal interaction boundaries for building energy simulations.

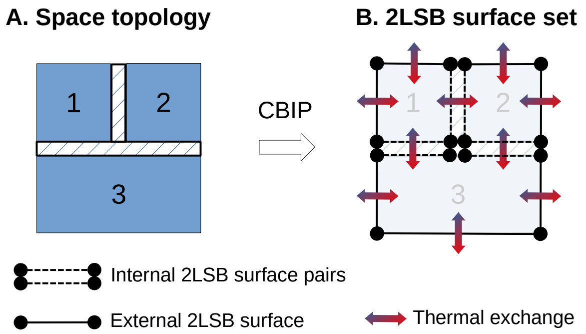

Figure 2: Diagram illustrating the generation of 2LSB surface set using the CBIP process.

A3. gbXML generation

The second-level space boundary (2LSB) surface set generated in step A2 is used as input to an ETL process that generates a gbXML file containing the required geometric data for further processing and the generation of an EnergyPlus input data file (IDF). In this ETL process, external 2LSB surfaces are directly transferred to the gbXML file, while each internal 2LSB surface pair is replaced by a single surface located on the middle plane between the parallel planes of the pair's surfaces. This single surface is obtained by the intersection of the projections of the pair's surfaces onto this middle plane. This ETL generation process from the 2LSB surface set to the gbXML geometric content is illustrated in parts B and C of Figure 3.

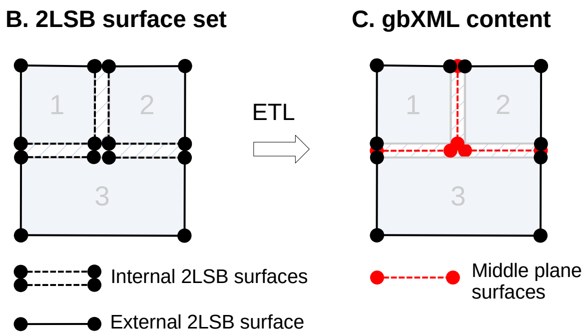

Figure 3: ETL process for gbXML generation.

B. Zoning scenario generation

The second stage, illustrated in block B of Figure 1, explores the generation of zoning scenarios informed by the HVAC topology that is established using knowledge graph technologies and geometric relation checking processes Wang et al. (2024b). The zoning scenarios are then used to simplify the full (baseline) building energy model.

B1. HVAC topology establishment

The HVAC topology can not only serve as the digital representation for configuring HVAC systems within the BEM model but also potentially influences the definition of thermal zones, enabling more accurate simulations. This topology is constructed by extracting and processing relevant information from BIM data within the Mechanical, Electrical, and Plumbing (MEP) domain and using knowledge graph technologies. Moreover, Brick, a building ontology developed by the Brick Consortium, can represent HVAC components, building spaces, and the logical relationships between them by creating digital counterparts. It also provides a standardised vocabulary for describing MEP and architectural elements, facilitating the integration of diverse data sources and ensuring interoperability across systems.

Establishing the HVAC topology involves transforming HVAC data from IFC files into a knowledge graph. This transformation incorporates the Knowledge Graph Generator (an ETL tool), the Geometric Relation Checker (GRC) proposed by Lilis et al. (2025), and a knowledge graph restructuring process. By leveraging the GRC tool, missing semantic connections between HVAC components can be identified based on their geometric relationships. These are then integrated with existing semantic links to complete the relationships within the knowledge graph. The resulting HVAC topology is precise and scalable, accurately describing the system configuration and supporting advanced building simulations.

This process was developed in our previous work, as detailed in Wang et al. (2024a,b). Figure 4 presents an illustrative example of the digital representation of an AHU system through the establishment of HVAC topology based on BIM data.

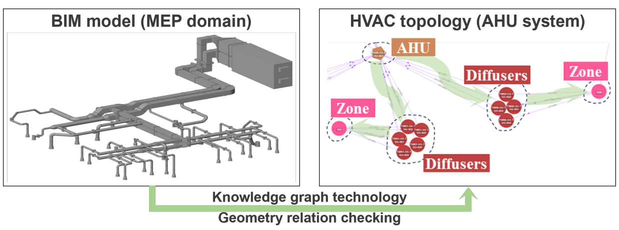

Figure 4: Brief illustration of the HVAC topology establishment process.

B2. Zoning rules and scenario generation

A set of thermal zoning rules is proposed to generate appropriate scenarios, considering HVAC information, geometric relationships, and internal heat gains. The rules specify that spaces may be merged into a single thermal zone if they (1) are adjacent to one another (vertically or horizontally), (2) serve the same functional purpose, and (3) are served by the same AHU.

Figure 5 illustrates the zoning process using a knowledge graph representation (i.e., HVAC topology). It shows that if an AHU serves only a single space, it does not affect the zoning process, whereas AHUs serving multiple spaces influence the zoning configuration. In subfigure (2), the boxes related to AHU-2 and AHU-3 indicate the merging of IfcSpace entities into thermal zones, whereas the box associated with AHU-1 highlights that no merging occurs. These zoning rules ensure that rooms with similar attributes, such as occupancy density and equipment loads, are merged into the same thermal zone. Additionally, it ensures that rooms sharing the same cooling or heating setpoint can be merged into one thermal zone, as the same AHU serves them. This approach also ensures that the resulting thermal zones are both energy-efficient and reflective of real-world operational conditions. Additionally, inter-floor and intra-floor zoning constraints are introduced to divide the generated scenarios into two distinct groups, enabling a deeper analysis of how zoning affects energy demand variations.
Consequently, if N AHUs in the HVAC system influence the zoning process, 2^N zoning scenarios will be generated separately for inter-floor and intra-floor constraints.

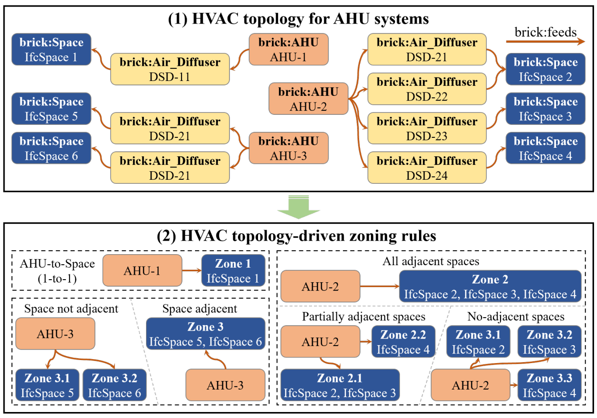

Figure 5: Illustration of HVAC-informed zoning scenario generation using knowledge graph technologies.

C. Model simplification and enrichment

This subsection comprises two parts linked to respective processes illustrated in block C of Figure 1: building geometry simplification and model enrichment. Together, they create a seamless, automated, and robust workflow for transforming building models from BIM to BEM with thermal zoning. The workflow efficiently simplifies complex geometric data to produce a simulation-oriented building model, which is then enriched with essential information to create a fully simulation-ready BEM model.

C1. 2LSB surface set simplification

The Second-Level Space Boundary (2LSB) surface set of the full BEM model generated in Part A of the framework presented in Figure 1 may not be suitable for building performance simulation software, such as EnergyPlus, due to its geometric complexity. Specifically, if the 2LSB surface polygons of the BEM model have curves approximated by multi-segment polylines, the triangulation of these surfaces can result in a significantly increased number of triangles. This increased number of triangles per surface imposes a substantial computational burden on simulation execution, making the overall building energy performance simulation process unfeasible.
A polygon simplification routine is applied to reduce this polygon complexity, as illustrated in Figure 6. More precisely, a point P_i is removed from the boundary of a polygon if two conditions are met:

1. The length of the line segments $\overrightarrow{P_{i-1}P_i}$ and $\overrightarrow{P_iP_{i+1}}$ is smaller than a length threshold L^{th}.

2. The cosine of the angle formed by the line segments $\overrightarrow{P_{i-1}P_i}$ and $\overrightarrow{P_iP_{i+1}}$ differ from one by a quantity less than an angle threshold A^{th}.

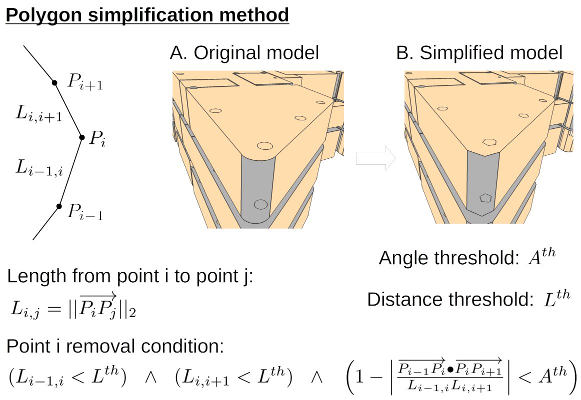

Figure 6: Illustration of the applied polygon simplification process.

As illustrated in Figure 6, the polygon simplification method reduces the circular holes and curved corners of the slabs displayed in part A into simple hexagons and polylines, displayed in part B, respectively.
Using as input the simplified 2LSB surface set obtained after applying the polygon simplification process described previously and the spaces to zones merging rules defined in an input txt file, several simplified BEM geometric models in the form of gbXML files can be obtained. To generate these merged BEM geometric models, a Simplification Tool called SMT (analyzed in Lilis et al. (2019) and used in Sayegh et al. (2024)) is applied to the full BEM geometric model generated in Step A2 using the spaces-to-zones merging rules defined in the input txt file, as illustrated in Part A in Figure 1. SMT merges neighbouring 2LSB surfaces by utilizing the surfaces defined by the gaps among the building's space volumes as connecting surfaces. This merging process is applied to 2LSB surfaces associated with spaces that belong to the same thermal zone.

C2. Model enrichment for BEM

This study introduces a seamless and automated workflow for BIM2BEM integration with thermal zoning, as shown in Figure 7. Batch simulations are conducted using EnergyPlus, which requires simulation-ready IDF files that include detailed descriptions of building geometry, material properties, equipment specifications, system configurations, and other simulation parameters.

As outlined earlier, building geometry models with varying thermal zoning configurations are generated in gbXML format. Using the OpenStudio SDK, these models are converted into IDF format for EnergyPlus simulations. In the Python environment, GeomEppy is employed to automate the assignment of external windows based on the wall-to-window ratio. Attributes of space entities related to internal heat gains are mapped to the appropriate fields, e.g., the People, Lights, and ElectricEquipment classes. Furthermore, by utilising RDFLib and Eppy, the HVAC topology and IDF editing processes are seamlessly integrated into a single Python-based platform, ensuring an efficient and consistent workflow.

In general, to enrich the geometric BEM model, key information includes building fabric, internal heat gain densities and schedules, AHU-related HVAC systems, and building control logic (derived from BMS manuals). This integrated enrichment process ensures the generation of simulation-ready models tailored for EnergyPlus, with further details available in Wang et al. (2024b).

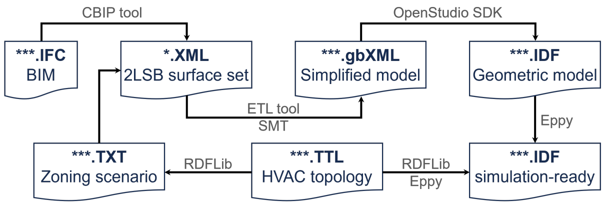

Figure 7: Diagram of the proposed BIM2BEM workflow incorporating thermal zoning.

Case study

The proposed workflow was applied to BIM data from One Pool Street (OPS) at UCL East Campus, London, a multi-functional building featuring an advanced energy system. This system includes 9 Air Handling Units (AHUs) equipped with cooling and heating coils to supply fresh air to large primary-function rooms. Fan Coil Units (FCUs) and radiators regulate room temperatures in other areas. The AHUs are centrally controlled by the building management system, ensuring efficient and seamless operation. This centralised control design highlights the importance of analysing zoning methods for the spaces served by the AHUs, as it enables more precise energy demand assessments and enhances system optimisation.

Data preprocessing

Figure 8 (a) presents the geometric IFC file of the BIM model for OPS, which includes the space elements only, and Figure 8 (b) depicts the previously generated HVAC topology. This BIM model in IFC4 format contains a total of 166 IfcSpace entities, which will be converted into thermal zones for building performance simulation. However, the external wall in the BIM model lacks openings, requiring windows to be defined using a window-to-wall ratio for simulation. This ratio can be determined based on building design regulations or relevant literature. Moreover, the HVAC topology, derived from MEP-BIM data and further validated against design drawings, consists of nine AHUs serving 43 spaces. These spaces are subsequently aggregated into relevant thermal zones to facilitate the analysis of zoning impacts on energy performance.

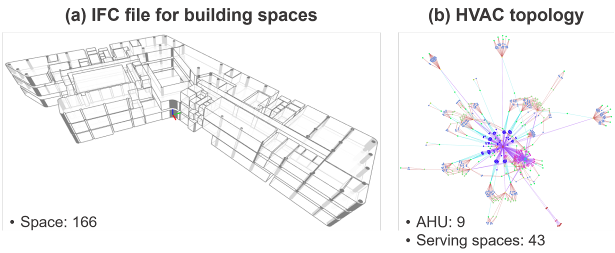

Figure 8: 3D Visualisation of (a) IfcSpace-related IFC file and knowledge graph of (b) HVAC topology.

Zoning scenarios

Based on the proposed HVAC-driven zoning rules, 9 AHUs were initially considered for scenario generation. However, the generated HVAC topology revealed that two of these AHUs exclusively serve a single space and, therefore, do not impact the merging process. The remaining 7 AHUs determine the zoning configurations. Consequently, the number of spaces to be merged was 41. For each AHU, a binary variable (1 or 0) was assigned to represent whether the spaces it serves were merged (1) or not (0). This approach resulted in $2^7 = 128$ distinct zoning scenarios. To account for both inter-floor and intra-floor zoning constraints, the scenarios were generated in two separate sets, each corresponding to a distinct constraint type. This process yielded 128 inter-floor zoning scenarios and 128 intra-floor zoning scenarios, resulting in a total of 256 scenarios that comprehensively capture the potential thermal zone configurations.

For each of the 256 scenarios, an independent gbXML building geometry model was generated. In these models, the spaces were merged into thermal zones based on the defined zoning rules. Additionally, the associated wall structures were automatically modified and reorganised to reflect the newly formed thermal zones accurately. These adjustments ensured that the generated gbXML models accurately captured the geometric changes resulting from zone merging, thereby enhancing the precision and reliability of simulations.

Results and discussions

This section explores the performance of the proposed BIM2BEM workflow with thermal zoning, analyses the variations in energy demands across different zoning scenarios, and discusses the limitations.

Performance of zoning process

The workflow was executed on a standard laptop computer. Simplifying the full model (baseline) to create a simplified gbXML using thermal zoning took, on average, a few hundred seconds, depending on the spaces-to-zones merging scenario. The subsequent process, which involved converting gbXML to IDF and preparing the simulation-ready model, encompassing tasks such as configuring openings, internal heat gains, and HVAC systems using HVAC topology, took approximately 3 to 4 minutes. Moreover, the whole-year simulation using the Typical Meteorological Year (TMY) weather file of London required an additional 3 to 5 minutes. Consequently, a single iteration for simulation under one zoning scenario was completed in approximately 8 to 10 minutes. Given the building's scale (166 spaces), imperfect BIM data, and its geometrically complex structure, the proposed BIM2BEM conversion achieved notable speed and efficiency.

Figure 9 (a) illustrates an example of corner spaces during the zoning process, and overall views of the baseline model are provided in gbXML format and its simulation-ready model in IDF format, as shown in Figure 9 (b) and (c), respectively. The relevant spaces have been effectively merged into thermal zones, considering both intra-floor and inter-floor constraints. Additionally, automatic adjustments have been made to the internal and external walls. The visualisation highlights that the building geometry simplification has effectively transformed the corner arc into hexagons through a polygon simplification routine. The final BEM model contains complete and accurate geometric information, which is error-free for building performance simulation.

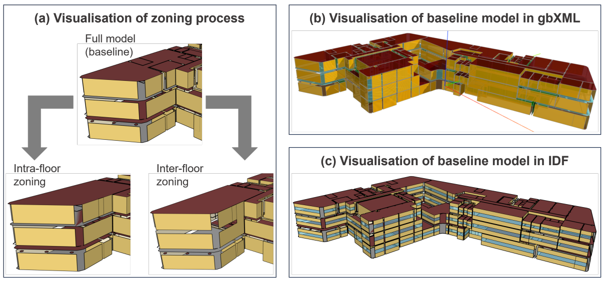

Figure 9: Visualisation of (a) example spaces during the zoning process, (b) the baseline model in gbXML format, and (c) the baseline simulation-ready model in IDF format.

Impact of zoning on energy demand

Figure 10 illustrates the cooling demand variations for zones served by AHUs across different zoning scenarios. The results show that as more spaces are merged, cooling demands decrease. Under inter-floor conditions, where zone merging is allowed across multiple floors, the cooling demand reduction can reach up to 9%. This decrease is attributed to the layout characteristics of AHU ductwork, which commonly distributes air supply across adjacent floors. Such a design enhances centralised management and spatial efficiency, making inter-floor merging particularly effective.

In contrast, when intra-floor constraints are applied (i.e., zone merging is restricted to within a single floor), the reduction in cooling demand is limited to approximately 2%. This demonstrates that intra-floor merging has minimal impacts on energy demand estimations. In scenarios where AHUs are designed to serve only single floors, limited zone merging results in negligible differences in energy demand after simplification. This is because a single AHU typically cannot comprehensively serve all spaces on a floor, thereby limiting the potential benefits of merging zones within separate floors.

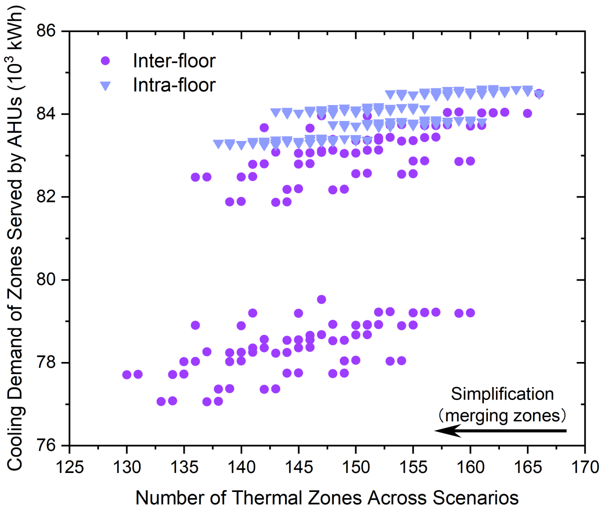

Figure 10: Cooling demand variations across different zoning scenarios.

Figure 11 illustrates the variations in heating demand across different zoning scenarios. Similar to the cooling demand, merging zones reduces heating demand. However, as the number of zones decreases, the reduction in heating demand becomes more uniform under inter-floor conditions. This indicates that the vertical and horizontal merging of spaces collectively influences overall heating demand. Under inter-floor conditions, the maximum reduction in heating demand reaches approximately 7% , while intra-floor constraints limit the reduction to approximately 3%. Observations show that inter-floor zoning can significantly amplify the effect of thermal zoning on simulation outcomes, particularly by reducing estimated energy demand. This underscores the importance of addressing both horizontal and vertical considerations, which were often overlooked in previous studies focusing solely on intra-floor configurations. In complex building HVAC designs, it is common for AHUs to serve multiple floors, further highlighting the need for robust geometric zoning methods and HVAC-informed zoning rules. Such approaches are crucial for avoiding overestimation of building energy demand and ensuring greater accuracy in simulation-based performance assessments.

These findings underscore the significance of appropriate zoning in practically simplifying models and achieving accurate simulations. Proper zoning reduces model complexity and enhances the precision of energy demand analysis for specific zones. Energy demand estimations using area-based metrics or modelling an excessive number of spaces often result in overestimations, highlighting the necessity for more advanced modelling approaches. In-

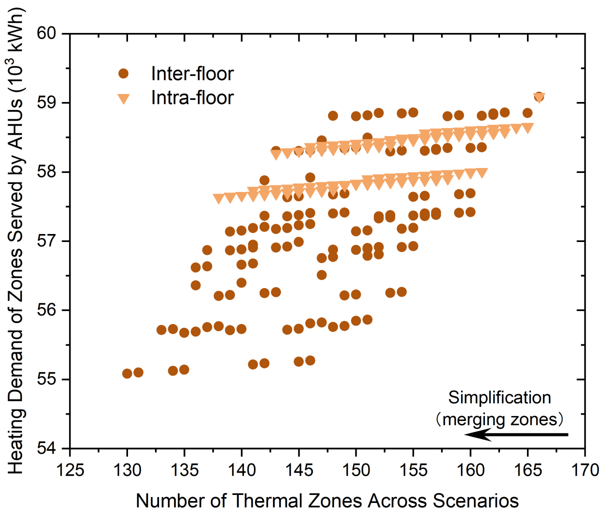

Figure 11: Heating demand variations across different zoning scenarios.

corporating robust and comprehensive zoning strategies within the BIM2BEM workflow can reduce these inaccuracies, resulting in more reliable and efficient HVAC system designs.

Limitations and further work

The proposed BIM2BEM workflow with thermal zoning relies on high-quality building geometry with limited design errors to maintain automation and ensure the accuracy of the resulting BEM model in IDF format. In this case study, the absence of window elements in the BIM data necessitated the generation of windows after zoning, which limited the ability to fully assess the workflow's performance when handling BIM data with detailed opening geometry. A potential solution to this limitation involves calculating the window-to-wall ratio from the BIM data and proportionally applying it to the external walls of the post-zoning BEM model. This approach could improve the robustness and reliability of the proposed workflow. Additionally, expanding beyond AHUs and incorporating more energy technologies could enable the development of more comprehensive and diverse zoning scenarios, further enhancing the applicability of the proposed BIM2BEM workflow.

Furthermore, zoning is not solely a geometric challenge. Beyond considerations of internal heat gains and HVAC information, additional factors such as thermal comfort and indoor air quality could be integrated into the zoning process by defining relevant zoning rules. This integration would facilitate the generation of simplified BEM models while providing a broader foundation for optimising building design. Future work will examine the proposed methodology's robustness and scalability by applying it to diverse buildings while also incorporating these factors to ensure its applicability to a wider range of building performance analyses.

Conclusions

To enhance the flexibility and accuracy of BIM2BEM workflows, this study proposes an HVAC-informed thermal zoning approach that simplifies building geometric models while ensuring seamless data interoperability across IFC, gbXML, and IDF formats. The methodology begins by generating a full BEM model (baseline) with complete geometric information from BIM data, defining thermal zones based on physical spaces delineated by construction elements such as walls and floors. A knowledge graph-based HVAC topology is then semi-automatically established to represent the real-world system, enabling the creation of HVAC-driven zoning scenarios that map IfcSpaces in BIM to thermal zones in BEM. Combined with the baseline model, these scenarios are introduced into a simplification tool to merge grouped spaces into thermal zones, reshape walls, and generate distinct geometric models for each zoning configuration. The resulting models are enriched with details such as openings, internal heat gains, and HVAC configurations (mapped from HVAC topology), creating simulation-ready BEM models. Validation of a complex building featuring advanced HVAC systems demonstrated the feasibility and effectiveness. Analysis of energy demand variations revealed that HVAC-informed thermal zoning led to up to 7-9% reductions in cooling and heating demands for inter-floor zoning and 2-3% reductions for intra-floor zoning, emphasising the importance of integrating HVAC information into the thermal zoning process for an accurate and adaptive BIM2BEM workflow.

Acknowledgements

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