

IFC TO BUILDING ENERGY PERFORMANCE SIMULATION: A SYSTEMATIC REVIEW OF THE MAIN ADOPTED TOOLS AND APPROACHES

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ABSTRACT

Due to the fast digital transition of the Architecture, Engineering, Construction, Owner Operator (AECOO) industry, a large amount of information is regularly exchanged between the involved participants. Handling and processing the exchanged data remain a major challenge for many related activities, such as Building Energy Performance Simulation (BEPS). In this context, the interoperability between Building Information Models (BIM) and BEPS models is still an unresolved issue. Many barriers prevent the full integration and data exchange between both models, such as geometry errors and missing data, which require a lot of human intervention. Thus, the process is still regarded as time, effort and cost consuming. In the literature, many works have been done to tackle this problem. In this paper, in the context of the BIM4Ren European H2020 project, which aims at providing BIMbased tools and technologies for fast and efficient renovation of residential buildings, a systematic workflow is proposed to handle the BIM to BEPS process and review the commonly adopted tools and approaches for each of its stages, i.e., from the generation of the BIM model, its geometry check, its data enrichment until its exploitation by a BEPS tools. The proposed workflow is based on the Industry Foundation Classes (IFC) as an information exchange standard for the BIM since it is an open data schema that is commonly used and compatible with most of the BIM software in the market. Finally, a practical approach to follow for a smooth and effective model transfer process is concluded.

INTRODUCTION

A BEPS model is an abstraction of the real building which allows to simulate its behaviour taking into consideration the influences of its geometrical details and physical properties and to analyze key performance indicators (KPIs). This model has a considerable potential that provides the ability to quantify and compare the relative cost and performance attributes of a proposed design in a realistic manner and at relatively low effort and cost.

On the other hand, a BIM model is defined by the National Institute of Building Sciences (NIBS) (2017) as a digital representation of physical and functional characteristics of a building. As such, it serves as a

shared knowledge resource for information about a building forming a reliable basis for decisions during its life-cycle from inception onward. Therefore, by definition, BIM models should also include the physical properties of the building and allow the analysis of its performance as well. However, the communication between BIM and BEPS models are not complete due to the different modelling objectives, modellers and data models that are currently used to build them. Moreover, there is always a need to perform a more sophisticated analysis for accurate results.

Some tools (e.g. Green Building Studio by Autodesk (2013) and Sefaira (2013)), which are integrated in a BIM modelling software, allow performing simplified simulations to give initial indications about the building performance using a controlled export of gbXML (Green building XML (2015)) models. However, as mentioned by Korolija and Zhang (2013), simplified models may lead to an error margin of 15% in addition to the error margin created by the simplification and assumptions while creating the energy models, thus leading to confusing results. Besides, they use simplified HVAC models with generic inputs which doesn't reflect its real performance.

Differently, the other tools, that allow the desired sophisticated analysis such as IES-VE (IES (2019)) or Energy-Plus (U.S. Department of Energy (DOE) (2020)), require, in most of the cases, a complex data exchange with the BIM modeling tools such as Revit by Autodesk (2020) or Archicad by GraphiSoft (2019), which creates many interoperability problems, not just in terms of the energy simulation but the whole asset management. This exchange is mostly done by the use of Open BIM data schemas, such as the Industry Foundation Classes (IFC, developed by buildingSMART (2013)) and gbXML, which are mainly created to solve the interoperability issues. The popularity of these two schemas led many leading AECOO software companies to implement support for IFC and gbXMLbased exchanges within their BIM authoring suites, yet these data schemas do not allow for an accurate, consistent and complete data exchange and thus create many problems such as geometrical errors and missing or incorrect data. This leads to a deficiency in the interoperability process, which prevents users to take advantage of valuable information during design, commissioning and operation.

Addressing this issue will enable a two-way information exchange to speed up the design process and facilitate digital design. Therefore, a wide variety of attempts have been proposed to establish an automated data exchange between BIM and BEPS tools. This paper aims at providing a systematic review of these attempts and proposing a general workflow that will be adopted in the BIM4Ren project. For each step of the proposed workflow, a list of different tools that can be used is provided together with advantages and drawbacks of each tool.

BIM4Ren context

BIM4Ren (2018) is an H2020 funded project, which stands for Building Information Modelling (BIM) based tools & technologies for fast and efficient RENovation of residential buildings. It aims at exploiting the BIM potential for the energy renovation of existing buildings for the whole construction value chain.

An expeditious energy retrofit of the existing building stock is required to successfully achieve the 2030 climate and energy framework key targets by having at least 40% cuts in greenhouse gas emissions (from 1990 levels), at least 32% share for renewable energy, and at least 32.5% improvement in energy efficiency. Thus, in order to ensure the acceptance of the refurbishment culture within the AECOO sector, significant progresses are necessary: (i) improve the quality of the renovation, (ii) reduce the time of phases and inter-phases (planning, design, construction, operation, and maintenance), (iii) minimize the impact on tenants, and finally (iv) guarantee that cost/benefits targets are accomplished among other predefined KPIs. Moreover, coordination among stakeholders during all phases is fundamental to ensure tight deadlines and overcome the common fragmentation of the AECOO sector. BIM4Ren aims to address all these objectives by developing a platform that integrates different innovative tools that can be used in all the stages of the renovation. Doing that, a technical development is needed and a proposal of extending the IFC schema is submitted. Furthermore, a communication with standardization bodies and similar research projects is conducted to extend the benefits of the research outcomes. One of the technical challenges is the interoperability between BIM models and BEPS models, which is a key factor that affects all the previous mentioned processes. This paper is focusing on this issue.

IFC vs gbXML

Open BIM is a universal approach to the collaborative design, realization, and operation of buildings based on open standards and workflows, that aims at tackling interoperability issues between different BIM software. The main purpose of Open BIM data models, is to allow for a smooth data exchange between the different tools in the AECOO industry. IFC and gbXML data are examples of open BIM models. They are the most commonly used in the process of BIM to BEPS and there is a big debate on

the data model that best fits in this process. In the BIM4Ren project, IFC is the main exchange format between the different tools used within the project. A further extension to the IFC schema will be proposed in favor of the BIM to BEPS process. In this section a brief description of the main differences between IFC and gbXML data models is provided to further explain the choice of the IFC format as the main focus in this paper.

Industry Foundation Classes (IFC), developed by buildingSMART (2013), is a standardized, digital description of the built environment, including buildings and civil infrastructures. It is an international standard (ISO 16739-1:2018), meant to be vendor-neutral, or agnostic, and usable across a wide range of software platforms and interfaces for many different use cases. IFC is a generic exchange format, that can be used across many domain specific software, thus contains a variety of data.

As for gbXML (Green building XML (2015)), it is a more simple schema and focuses on environmental data. It is now commonly adopted as a *de facto* standard by energy simulation software vendors. It is developed to facilitate the transfer of building information stored in BIM models, enabling interoperability between disparate building design and engineering analysis tools. It is based on a consolidated web standard syntax XML, which is powerful in its expressiveness, and data structuring.

On the one hand, IFC adopts a relational approach to represent an entire building project, which results in a relatively complex data representation schema and a large data file size with the possibility to use the Model View Definition (MVD) format to filter the data based on needs. On the other hand, gbXML adopts a more flexible approach and relatively straightforward as the BEPS is its main focus.

In IFC files, it is possible to trace back all the semantic changes when one value of the element in the schema changes. In terms of geometry, the generic approach of IFC has the ability to represent any shape of building geometry, while gbXML only accepts rectangular shape, which is enough for energy simulation, Dong et al. (2007). One would say that gbXML would be more suitable than IFC as an exchange format between BIM to BEPS, as the gbXML has less layers of complexity and it is mainly designed for energy modelling purposes. However, to our knowledge, there are still limitations on what can be transferred between BIM and BEPS models for both formats. Within the framework of BIM4Ren project, different BIM models from the project pilots and test models have been used to test transition process. IFC and gbXML models have been generated from each BIM model (at the date of this paper), and a comparison between the generated models has been conducted. The transition process output is about 90% similar in both models (same geometry errors, missing items, etc.), though IFC has the ability to automatically maintain semantic integrity.

Furthermore, IFC is widely used as an exchange format between most tools in the AECO industry, while gbXML is only used for BEPS tools. Thus, it would make more sense to further develop IFC models than gbXML for the reasons stated earlier. Another suggested approach within the BIM4Ren project would be fixing IFC files then transferring it to gbXML file ready for simulation. There are some existing tools and methodologies that convert IFC to gbXML, using the BIM tools to import the IFC such Revit by Autodesk (2020) then convert it to gbXML, or using a conversion tool such as IFC to gbXML converter developed by Maarten (2016). Moreover, there are other tools that convert gbXML to IDF, yet these tools are not addressed in this paper.

Current exchange problems and limitations

The model Level of Development (LoD) describes the level of detail to which a model is developed and its minimum requirements. The LoD is accumulative and should progress from LoD 100 at Conceptual Design to LoD 400 at completion of Construction, as mentioned by Bloomberg et al. (2012). A BIM model has usually a higher LoD than a BEPS model would require. There are fundamental differences between a BEPS model that is used to analyze the building performance and a BIM model that is used to generate construction documents, and the ability to cycle through design options in a timely manner requires understanding of both models. From the BEPS modelling perspective, it requires only relevant information w.r.t. the question at hand, reducing variables, thus reducing analysis time. From the BIM modelling perspective, the visual character of the overall model is important to convey the design intent as well as the detail to express the layering of ideas. A wall with multiple layers will be modelled in a BIM model as a geometry with multiple surfaces with the relevant thickness of each of these layers, while in a BEPS model, it will be modelled as a single surface with the layers as information as seen in Figure 1. That fundamental differences lead to many geometrical mistakes and model errors. When carrying out design

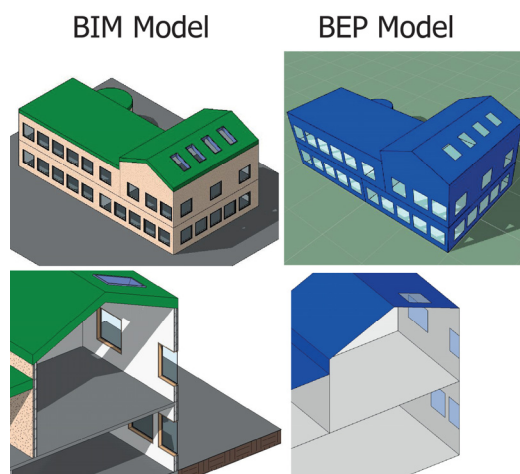


Figure 1: BIM vs BEPS models

exploration at different stages of the process, it is advisable to utilise the appropriate level of detail for the analysis, making it easier to focus on outputs that can inform the design. A large amount of details at the early stages can cloud the fundamental design decisions.

The main problems in the exchange process between BIM and BEPS models can be classified according to the following data quality metrics: (i) Accuracy, (ii) Completeness, and (iii) Consistency, as described by Katsigarakis et al. (2019). As for the data accuracy, it refers to the degree to which data correctly represents the “real-life” objects they are intended to model. The IFC file has to be free of geometrical errors (clashes, space definition errors, surface orientation errors). As for completeness, missing or incomplete data is one of the most important data quality problem in many applications, as mentioned by Sattler (2009). Many BIM elements support information exchange identifying the thermal performance characteristics that are needed to run energy analysis, however, BIM users are not required to specify these values or they tend to use default ones. Therefore, a consistent thermal analysis cannot be performed without the appropriate characteristics. The IFC file has to contain all the needed information to perform an energy simulation such as:

- Physical and thermal properties of the building envelope;
- 2nd level space boundary information (See Figure 2), i.e., surfaces through which thermal energy flows, whether among internal building spaces or between a building space and the buildings’ outside environment such as air/ground;
- Some contextual data (schedules, gaining profiles, etc.).

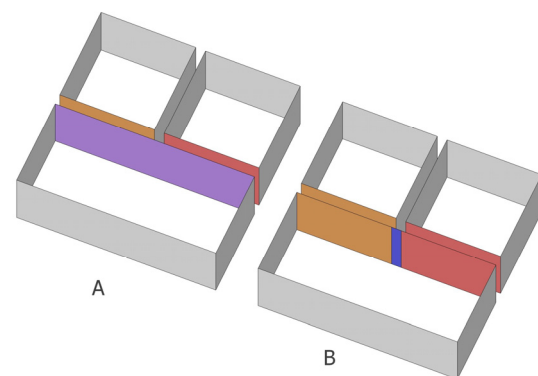


Figure 2: 1st (A) and 2nd (B) space boundaries

As for consistency, it refers to the degree to which data managed in a system satisfies specified constraints or rules, Sattler (2009). The IFC file has to be consistent with the BIM model in aspects such as location, units and orientation.

BIM to BEPS-based Workflow

This sections briefly overviews mainly adopted tools and approaches for each stage of the BIM to BEPS workflow (See Figure 3), namely (i) the identification

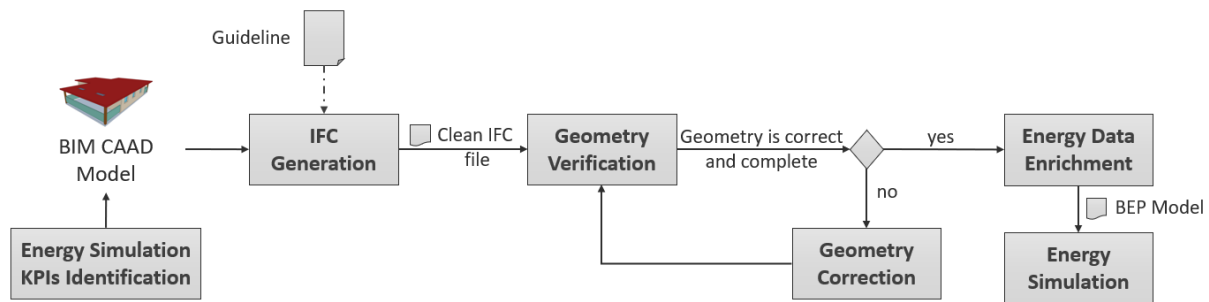


Figure 3: A systematic BIM to BEPS overall workflow

of energy simulation KPIs, (ii) the generation of the IFC file, (iii) the verification of its geometry and its correction if needed, (iv) the enrichment of the IFC file with required energy data and (v) the energy simulation based on the enriched IFC file.

Energy Simulation KPIs Identification

An initial step in the BIM to BEPS workflow is to identify the energy simulation needs or the questions that the final stage of the process should answer. These needs should be defined as KPIs, which are application dependent. For instance, in the context of the BIM4Ren project, a set of energy KPIs has been defined for the renovated buildings such as the primary energy demand and consumption and the energy savings.

IFC Generation

A big percentage of the errors encountered at the simulation phase is due to how the geometry is generated in the first place. The transition from BIM to IFC may produce errors that need to be fixed before importing the IFC into a BEPS tool, as those errors will still be reflected in the energy model. An example can be seen in Figure 4. Besides, BIM models can include many unnecessary details, because they are usually generated by a BIM specialist for a purpose related to their own domain rather than energy modelling.

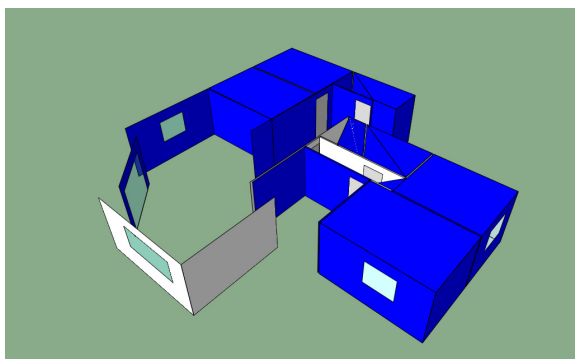


Figure 4: IFC model imported to IES-VE energy simulation software

As mentioned earlier, most of the BIM authoring tools (such as Vasari, Revit by Autodesk (2020), and ArchiCAD by Graphisoft (2019)) offer IFC export/import

features. However, the IFC generation process shall result in a clean IFC file, i.e., it needs to be at least accurate and consistent without any geometrical errors and imperfections. Thus, it cannot be directly usable for such a workflow. The whole process needs to be wisely controlled. For BEPS, the purpose is not just to generate a BIM model, but rather generating a BIM model with a low LOD 100 or 150.

Although there are many geometry error detection tools (e.g., the Geometric Error Detection (GED) tool introduced by Lilis et al. (2015), the IFC Validator implemented by De Laat and Van Berlo (2013), etc.), there should be a step by step guideline on how to generate a clean IFC file to make the process more reliable and less vulnerable to modelling errors. In this line of thoughts, a summary of design guidelines and best practices to generate an accurate and consistent models is listed below, collected from different sources such as Giannakis et al. (2019), and the IES-VE modelling guidelines by IES (2018):

- A coordination with the design team and the BIM manager regarding the required LOD is necessary to keep the model simple, allow a successful IFC generation, and reduce the redundancy and geometrical errors;
- Rooms, Spaces, Zones have to be correctly created and, at each stage, a check needs to be done to ensure they are fully bound and their volumes are correctly represented;
- There should be no air gaps within the full external boundary of the building model and all volumes should be accounted for including ceiling, roof voids and risers;
- Model element properties have to be checked before exporting the IFC file;
- Both IFC2X3 and IFC4 schemas should contain the space boundary (IfcRelSpaceBoundary) entity, which defines the physical or virtual delimiter of a space and its relationship to the surrounding elements. It is important to export this entity when the IFC model is generated.

As per the findings from the conducted tests within the BIM4Ren project on models generated in IFC2X3 vs IFC4 versions, the latter works slightly better, producing less errors. However, since the difference is not that significant, this has

no impact on a recommended use of IFC version in general, as IFC2X3 is still more commonly adopted than IFC4.

It is worth mentioning that, between Revit and ArchiCAD, the most common BIM modelling tools, the latter enables a more precise definition of zones, space sizes and boundaries (inner edge or reference line). Moreover, it allows a manual modification of these boundaries, which makes it a more accurate tool for IFC file generation than Revit. The latter automatically generates these spaces and doesn't allow for manual modifications.

Geometry Verification

The main purpose of solving the interoperability problems between BIM and BEPS is to save time and resources. The most time consuming work in energy modelling is creating the geometry and assigning the main inputs such as construction details, internal gains and operation profiles. Although the BIM designer is provided with a step by step guideline in the previous stage, the geometry verification remains crucial in order to double check accuracy, completeness and consistency of the generated IFC file. There exist many tools that automatically verify the geometry issues mentioned in the IFC Generation section. Some of these tools are:

- **Geometric Error Detection (GED)** tool by Lilis et al. (2015), which is developed in the context of OptEemAL (2019) and BIMplement (2020) H2020 projects. The GED tool detects clashes, surface errors, and space incorrect definitions in IFC4 files. Detected errors are reported in an XML form. Yet, so far, the tool is not publicly available.
- **The IFC Validator** implemented by De Laat and Van Berlo (2013) is an open source plugin for BIMserver 1.5, limited to IFC2x3tc1. The tool checks for a set of common requirements, among which the geometry of some objects. However, these requirements strictly depend on Dutch norm documents.
- **Advanced model checking and quality assurance tools**, such as Solibri Model Checker by Solibri (2016) and Naviswork by Autodesk (2016), commonly used by BIM professionals, where users can define different checking rules that fit their needs, then create issues that can be reported back to the design teams to fix them. These tools support IFC2 and IFC4 versions. Yet, model checking features are not freely available to the users.
- **BIM Interoperability tools** developed by Autodesk (2019) are integrated into Revit, their modelling software, which comprises different tools to help the stakeholders with their BIM workflows. Model Checker is one of these tools. It enables the creation of checksets to check the model against some rules. This could be handy and fast in avoiding errors before even creating the IFC model or exporting it to another checking tool. As it is a part of Revit, it is not a freeware and cannot be used as a standalone.
- **Simergy** developed by Digital Alchemy (2020) is a BIM-based energy simulation and energy performance analysis tool. It integrates a checker, which verifies the integrity of the model at any point. However the free version is limited in terms of size and complexity of IFC files. The professional version has more features, yet it is paid.
- **IES-VE** developed by IES (2019) has an integrated BIM Navigator (step by step guide), which allows for the verification of the geometry of IFC2x3 and IFC4 files before importing them. The tool doesn't have a free version. Besides, it is more oriented towards the gbXML format.

Geometry Correction

If the IFC file's geometry is not accurate or consistent, errors that have been generated by the tools listed above should be corrected. There are many tools that offer automatic or semi-automatic techniques for geometry correction. Some of them are already listed in the previous section for the geometry verification stage, while some others are dedicated to this stage only:

- **IES-VE** integrates a Modelling fixing algorithm, which heals geometrical errors, caps and fixes missing surfaces and holes. It also fixes the adjacency and 2nd level space boundary problems. Moreover, it has its own modelling tool ModelIT, which allows for a manual fixing of some geometries. However, these algorithms fix geometry issues after being run several times.
- **The IFC Space Boundary Tool (SBT)** introduced by Bazjanac, V. (2020) is a tool that generates required 2nd level space boundary information used in EnergyPlus. It is based on the Geometry Simplification Tool (GST) proposed by Bazjanac (2009), which first simplifies original IFC file and transforms it to gbXML file. The tool, however, is not comprehensive for the generation of 2nd level space boundary information as it misses out corrections to windows in curtain walls, floors and ceilings.
- **The Common Boundary Intersection Projection (CBIP)** is another tool for the generation of 2nd level space boundary information proposed by Lilis et al. (2017). CBIP takes IFC well-formatted files as input (STEP files) and outputs enhanced IFC files (STEP files). This is done in two major stages: (i) it identifies Common Boundaries (CBs) of architectural element pairs (mainly IfcBuildingElement, IfcOpeningElement, IfcSpace and IfcSite) contained in IFC files; (ii) it projects CBs and generates boundary surface topology elements (thermal elements, shading elements, opening elements, air boundary elements), which geometry and connectivity

information are added to the IfcRelSpaceBoundary2ndLevel entity in the IFC files. The tool is not yet publicly available for use.

- **The IFC Space Boundary Conversion tool** is developed by University of Dresden (2017). It transforms 1st level space boundary to 2nd level space boundary entities of IFC files according to the Space Boundary Implementation Guide of buildingSMART. Yet, the tool is limited to IFC2x3.

Energy Data Enrichment

The Enrichment process is relatively easier than the problem fixing phase. Although the IFC file's geometry is accurate and consistent, it still lacks required data for energy simulation, thus it is subject to energy data enrichment. The required input data for a whole-building simulation is listed below (some information is not supported in IFC2x3 or IFC4):

Climate: ambient air temperature, relative humidity, direct and diffuse solar radiation, wind speed and direction;

- Site: location and orientation of the building, shading by topography and surrounding buildings, ground properties;
- Geometry: building shape and zone geometry;
- Envelope: materials and constructions, windows and shading, thermal bridges, infiltration and openings;
- Internal gains: lights, equipment and occupants including schedules for operation/occupancy;
- Ventilation system: transport and conditioning (heating, cooling, humidification) of air;
- Room units: local units for heating, cooling and ventilation;
- Plant: Central units for transformation, storage and delivery of energy to the building;
- Controls: for window opening, shading devices, ventilation systems, room units, plant components;
- Energy costs, incentives, sources information;
- Renewables.

For existing buildings:

- Existing improvements;
- BMS data log or spot checks.

The objective of this process is to complete the missing data, thus it will generate a **complete BEPS Model** ready for simulation. This can be done manually using the list of the Energy modelling tools listed in the next section (Energy Simulation), or as an automated or semi-automated process as listed in this section. In this context, many works have been done in order to enrich the IFC through semantic web technologies, such as the use of ontologies. The latter come down to formal conceptualizations of given domains through entities and relations between them, Staab and Studer (2010). Ontologies are particularly powerful in handling semantic interoperability, i.e., linking vocabularies of different standards and data models and extending them.

Below, a list of ontology-based and non ontology-based works is provided:

- **District Data Model (DDM):** in OptEEmAL project, Costa et al. (2016) propose an ontologybased platform in order to support retrofitting design of energy-efficient districts, facilitate the data integration and ensure interoperability among multiple simulation tools. DDM is defined in this platform, based on the federation of three ontologies: (i) IfcOWL by Pauwels and Walter (2016) to represent building geometry, construction materials, devices and spaces; (ii) CityGMLOWL by Metral and Falquet (2016) to represent the geometry of multiple building envelopes, urban systems, urban areas, etc; and (iii) SimModelOwl introduced by Pauwels et al. (2014) from the work of O'Donnell et al. (2012) to represent data required for energy simulations. The DDM also integrates contextual data added manually to represent weather data, operation schedules of building devices, building typologies, sensors monitoring, energy prices, etc. Practically, after validating the IFC completeness and correctness, IFC files are converted into semantic web data models, mainly Resource Description Framework (RDF) files following the knowledge provided by the ifcOWL ontology. The generated RDF files are then combined with other RDF files describing data from CityGMLOWL and SimModelOWL. Queries are applied on RDF files in order to generate outputs (e.g., Input Data Files or IDF) used by simulation tools (e.g., EnergyPlus).
- **Energy Enhanced BIM (eeBIM):** in the context of eeEmbedded (2017), Kadolsky et al. (2014) propose to enrich an IFC file by integrating additional useful energy information such as climate and occupancy data. The integration of the different domain models is done through an ontology-based approach. In a first step, given a clean IFC file, a semantic web model is generated based on the knowledge provided by the ifcOWL ontology. In a second step, an energy BIM (eBIM) model is generated by using the ontology reasoner and a set of logical rules. The eBIM contains energy relevant information such as outdoor windows, building facades, space boundary information, etc. In a third step, the BIM model is further extended by adding additional energy relevant information such as climate data, occupancy data, material data, etc. This corresponds to the eeBIM, which is ready for energy simulation.
- **Property Enhancer:** this tool is developed in the contest of BIM4Ren project. It is designed to improve the Level of Information (LoI) of BIM files. It can either enrich the IFC files automatically by adding some properties retrieved from external databases or manually by choosing from different renovation packages of existing catalogues.

Energy Simulation

After successfully completing all previous steps, the energy simulation phase is a relatively easy one, depending on the software used for energy simulation, and the methodology to follow. There are two approaches in this phase: (i) either to query from ontology models a compatible energy simulation tool's format such as IDF for EnergyPlus (e.g., the case of OptEEmAL project), (ii) or import the (manually or automatically) enriched IFC file directly to a compatible software as IES-VE and IDA-ICE8. There are many available simulation software. A list can be found in the BEST directory¹.

A list of energy simulation software capable of importing IFC files is provided below:

- RIUSKA (DOE-2 based, Import/Export), Granlund (2010);
- IDF Generator with EnergyPlus, U.S. Department of Energy (DOE) (2020);
- IES-VE, IES (2019);
- IDA ICE, EQUA Simulation AB (2020).

The core tools in the field of BEPS are multi-domain, dynamic, whole-building simulation tools, which provides users with the answers for the predefined KPIs.

CONCLUSIONS AND FUTURE WORK

This paper presents the main problems limiting the full integration and data exchange between BIM and BEPS models while focusing on the IFC as the main open international standard for the BIM model. Then it gives an overall overview on the main workflow from BIM to BEPS and reviews commonly adopted tools and approaches for each of its stages. The following key points are concluded and will be implemented in future work in the context of the BIM4Ren H2020 project in order to improve energy renovation of residential buildings:

- Energy Simulation KPIs Identification: define a set of KPIs that should be answered by the energy simulation;
- IFC generation: provide a step by step generic guideline to generate a clean IFC file regardless of the used BIM authoring tool;
- Geometry verification: develop BIM-based web services that implement academic prototypes that are not publicly available but identified as relevant for the detection of the correctness and completeness of the IFC file, such as the GED tool;
- Geometry correction: develop BIM-based web services that implement academic prototypes that are not publicly available but identified as relevant for the enrichment of IFC file with 2nd level space information, such as the CBIP algorithm;
- Energy data enrichment: use semantic web technologies in order to enrich the correct and complete IFC file with missing energy related

data. A step forward towards this objective has recently been done by proposing a linked data model for the BIM4Ren project, as described by Bourreau et al. (2020);

- Energy simulation: develop BIM-based web services that exploit required IFC and non IFC data (from a semantic web format) in several energy simulation tools such as IES-VE and EnergyPlus.

To take advantage of the ability to integrate BIM and Building Performance Analysis, BIM models needs to be developed following the proposed workflow. Moreover, such a workflow could be standardized, leading to the development of different interoperable modules that focus on specific issues (i.e., geometry checking, semantic enrichment, etc.), while complying to standardized input/output interfaces. The definition of this modular workflow and its interfaces could be proposed to the dedicated Energy Simulation task force of buildingSmart International. The usefulness and accuracy of the analysis results depend greatly on the quality of the input data.

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