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Cross information and BIM interoperability tools for energy retrofit analysis

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Abstract. In recent years the Building Energy Modelling (BEM) has emerged. It is based on BIM technology, that uses pre-designed BIM models to create an input for BEM tools, providing an opportunity to make BEM a time-saving, practical and accurate process. This format works quite efficiently for geometric information, while it presents interoperability issues due technical data loss. This study aims at creating a tool that collects and imports information in the BIM model in order to be exported by the IFC standard and read by the energy analysis software, crossing from BIM to BEM model. Considering the complexity of historic buildings' energy retrofit design, it is crucial to find and develop a fluid method that can automatically transfer the needed information, reducing considerably the time spent on preparing the BEM model. To achieve this goal, an open source Visual Programming Language tool and a specific Property Set for IFC exportation have been used. It was possible to transfer the needed parameters, while restricting as much as possible the human's transcription mistakes. This approach has been applied to the energy preliminary analyses of an historic farmstead near Milan, proving the decrease in time spent on transcribing, exporting and checking parameters. Due to the possibility of saving and reproducing VPL scripts in different BIM projects, the results of this study will be easily replicable and could be a usable tool for designers.

Keywords – BIM cross information, IFC Model View Definition, BIM interoperability, from BIM to BEM

1. Introduction

In the last decades, designers have paid more attention to energy saving systems in order to minimize the increase of buildings energy consumption. This goal is possible if buildings are properly designed, constructed and operated.

To gain as much as possible from every energy aspect of the building it is important to involve the energy professionals and conducting an appropriate analysis since the first design phase; unfortunately, this process is still not appropriately established in the design phases and researchers all over the world are studying tools to improve the collaboration between professionals and the interoperability between their design software. Due to the importance of this process and the current questions on how to apply the energy discipline to all design phases, this research applies an information workflow based on the Level Of Information Need to the energy analysis cross information process. This workflow operates inside the BIM (Building Information Modeling) method: the basic element of this methodology is the information model, more commonly called the digital model, that is a virtual model that contains geometric and non-geometric information concerning the entire life cycle of a building. This methodology brings substantial benefits linked to the exchange of information between all the figures involved in a project, aiming towards a collaborative design called integrated design.

In recent years the Building Energy Modelling (BEM), that uses the pre-designed BIM model to create an input for BEM tools and energy analyses software, providing an opportunity to make BEM a time-saving, practical and accurate process has emerged. The BEM technology gives the opportunity to evaluate alternative design choices, compare and select systems and subsystems, allocate annual energy budgets, achieve compliance with energy standards and economic optimization during the building design process.

This is even more important if considering historic buildings, due to their complexity and constructive features, so far from the modern energetic approach and technologies. The energy retrofit project of an historic building must be based on the correct preliminary assessment of the entire building performance and its energy potential; in this way it is possible to calibrate design effectively, without compromising the preservation and the testimonial value of the building itself.

In energy modelling simulations and information, the contribution of BIM is still mainly about exporting the building geometry and its architectural information, like material thickness, windows and doors dimensions, orientation and location. Unfortunately BEM does not yet benefit from a continuous and efficient information flow: energy-related information has to be manually re-entered into BEM tools, although it is already available in the BIM model.

In order to implement the interoperability between BIM authoring software and Building energy models a various amount of studies have been and are being developed. However, there is still room for improvement and this research aims to make a step forward, towards a more efficient interoperability with the tools at disposals to the professionals. Therefore, this study aims to use BIM technology to ease handling and driving energy data by defining a sort of data storage automation.

The paper, after an excursus on the latest scientific results about interoperability between BIM and BEM, is structured in two main parts: the first one frames the methods used to conduct the research, dealing with the definition of the Level Of Information Need for energy analysis and its integration in the BIM to BEM process. The second part will more in details the research steps and will share the results obtained by applying the method to historic buildings.

As part of the energy requalification project, attention is paid to the preliminary phase of investigation of the “as built” state, since it’s a decisive moment in the decision-making process of future intervention choices.

2. Literature review

The study conducted by H. Gaoa et Al. [1] analysed the current export methods with an exhaustive review to compare the current situation. Most of the IFC-based studied methods are still just focusing on the geometry translation from BIM to BEM, while all other required BEM data are selected by default or need to be filled in manually by the users. Only the material name/ID and material layers of the construction can be extracted from BIM to BEM. The relevant thermal properties do not really originate from the BIM model, but come from an external material library.

In terms of the thermal zones, gbXML-based methods have a better performance than IFC-based methods. Another work [2] studied the application of gbXML standard and showed the extension of data loss. The gbXML file had the required energy simulation data and was exported on Revit. However, there was some interoperability deficiency with this approach in the form of data loss. This interoperability deficiency was also observed throughout the third step between Revit and Autodesk CFD. Although the Revit and CFD simulation tools were directly linked, there was still data lost between them. When launching CFD software on Revit, material information was not retrieved directly. This information had to be regenerated, making this process relatively time-consuming.

The process of connecting BIM to energy simulation tools is a research subject that is highly developing in this period. Fawaz et al. [3] developed a Model View Definition which defines a subset of the IFC schema, which is required to perform thermal comfort performance through simulation for commercial office spaces. For a reliable data exchange, however, the current IFC release still needs to be expanded in order to provide additional data related to the building materials and their thermal properties.

A workflow of green building design assessment and rating, proposed by Seghier et al [4]., is based on the integration of Visual Programing Language (VPL) and BIM aims at developing a BIM-VPL based tool for building envelope design and assessment support to check the information model through Dynamo 1.2.1 scripting. It can extract the relevant information form the existing component in the Revit library then exporting them to an Excel spread sheet for ETTV (Envelope Thermal Trasmittance Value) assessment and rating according to Green Mark and GreenRE requirements.

Another interesting approach [5], that has been explored and applied (implemented?) even in this study, is the application of the VPL tool to rewrite and implement the IFC file, in order to improve the level of data interoperability between Revit and BEM Italian software Termolog. The study proved that is possible to add the material's thermal properties to the IFC file that will later be read by the BEM software. In short, the literature review has shown that there is still room for improvement in integration from BIM to BEM, in order to help avoid re-entering data already present in other models developed for the project. Achieving this goal would be considerably time-saving and would minimize the human transcription errors.

3. Method

Performing automated or semi-automated energy and indoor environment analysis requires all information relevant to the specific tasks to be clearly defined in the model. Therefore, understanding the level of detail needed for a simulation model is essential for a successful integration.

The Level Of Information Need, explained on standard ISO 19650, is the description of the information deliverable to fulfil a specific purpose for which the data are required. This concept was the starting point for this research.

Given the large amount of information that are involved in building energy analysis, the research has taken into account only the ones related to the building envelope, to define its property and its performance. In the built environment, this is the first analysis step to perform specially on historic buildings, due the complexity of their thermal behaviour, that often does not correspond to the standard building. To develop a framework that defines the extent and granularity of the information the study took into account the current European and national laws and standards (UNI 10351,13788,10077,6946,11300), national requirements (Minimal Environmental Criteria) and energy and sustainable certification protocols. As energy and sustainable certification protocol was considered the LEED for Historic Buildings (HB LEED) edited by the Green Building Council Italia. This particular protocol was chosen for the worldwide distribution that LEED protocols have in the green design and for its focus on Historic buildings that will be the case study to test the research information workflow.

A new cross information workflow to implement the interoperability and data transfer was developed and, for this purpose, the entire process, from data collection to its inclusion in the BEM software, was considered.

The first step was to analyse the possibility offered by the software and the open source standard to customize the information exchange, adding and selecting only the needed data.

With the BIM authoring software it is possible to customize the parameters assigned to the model's objects in order to add information to the default one. Shared parameters are definitions of parameters that you can add to families or projects. Shared parameters are also useful when you want to create a schedule that displays various family categories.

Once the parameters have been added to the model it is possible to export them in the IFC file through some customized property set. Some parameters, however, despite their correct transcription into the PSet file, are not exported in the IFC format. Specifically, for this study, IfcMaterialProperties class, even if properly mapped in the BIM software settings, in the current state of the software, is not exported; the absence of this class affects all the sub-entities that depend on it. As seen in a previous study [5] a possible solution is to rewritten the IFC file and add the material thermal information.

To better understand the informatic data transfer and its writing in IFC format, the reverse passage from BEM to BIM has been studied; the specific way of writing a data read by the BEM model was identified so that the IFC standard could correctly transfer it.

Ultimately a workflow has been studied to automate these data transfer from the Excel Level Of Information schedule to the IFC file; in order to achieve this, the VPL tool Dynamo, a plugin for Revit, that allowed to transfer data without having to manually rewrite them, was used.

4. Workflow application

Once the Level of Information Need is identified [6], the corresponding Revit shared parameters have to be added to the right objects that compose the building envelope: stratigraphic elements and windows. As stratigraphic elements are identified the objects that are composed by layers, like walls, roofs and pavements are meant; every layer of material has to be considered with its properties so that the BEM software can calculate the thermal transmittance of the entire envelope's element.

Once the shared parameters are assigned they have to be correctly valued, paying attention to their characteristics, whether they are to be considered instance or type parameters. Then they have to be exported in the *.ifc file through the PropertySet *.txt file.

For the thermal material properties was possible to modify the *.ifc text file and add the properties needed, in order to be automatically read by the BEM software. A custom material library was created with the specific thermal properties of the material used in the building.

At the end the so implemented *.ifc file, enriched with the necessary information according to the phase and purpose of the energy model, is exported in the energy analyses software Termolog.

Through Dynamo, a VPL plugin for Revit, was possible to link the Level of Information Need Excel schedule to the Revit model; other scripts allowed to write the shared parameters and assign them and their value to their relative objects. In this way the process described above was possible through a few steps and in a very short time. Combining the VPL and Python language it was possible to rewrite the *.ifc file with the thermal materials characteristics: to add the missing parameters it is necessary to write them in the appropriate form and add them to the ifc script. The VPL scripts developed to create the information workflow were five, since the creation of shared parameter had to be divided for system and component families:

- Script 1: creation and association of shared parameters for system families (stratigraphic elements)
- Script 2: creation and association of shared parameters for component families (windows)
- Script 3: valorization of shared parameters for system families
- Script 4: valorization of shared parameters for component families
- Script 5: writing material thermal properties in the *.ifc file

All this process and its tools (schedules, dynamo scripts, *.txt file) will be available in the Common -Data Environment, so that every designer can consult and share the parameters, providing the necessary information and completing the related Excel form.

The developed cross information workflow (figure 1) automates complex steps, which, if done manually, can lead to errors and waste of time.

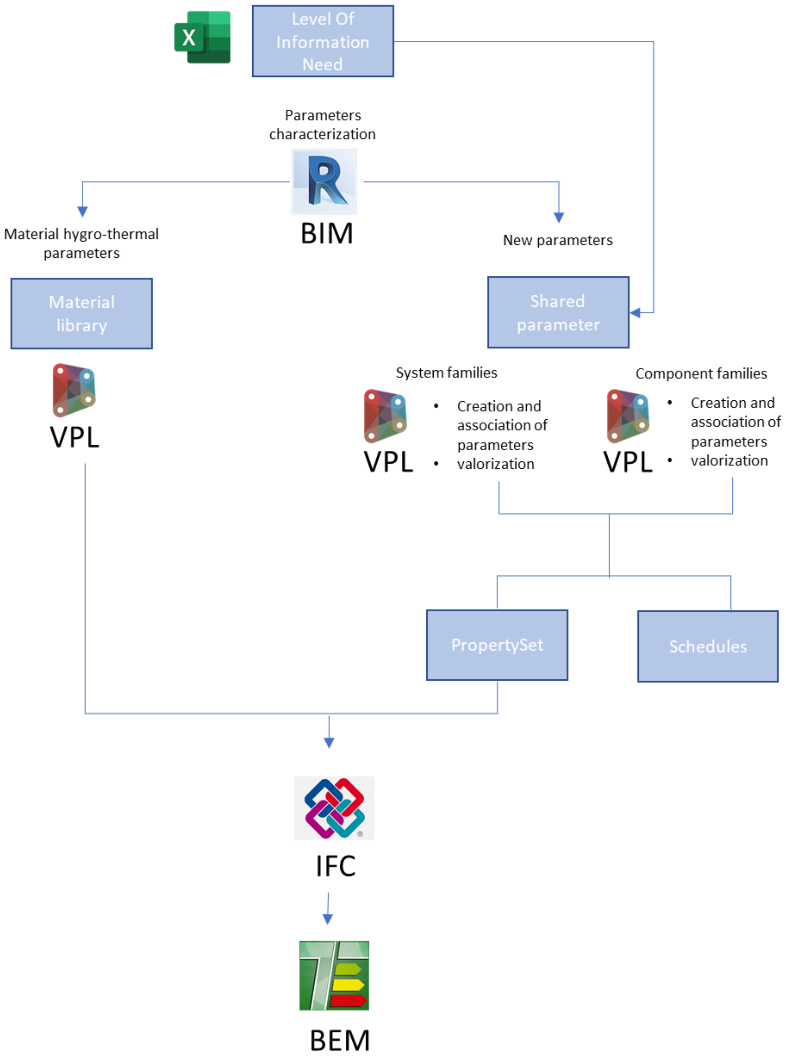

Figure 1. Cross information automated workflow

5. Results

The workflow was applied to a farmstead in Milan, Sella Nuova, which was built in the XV century. An accurate assessment of the energy behaviour of the building in its current state is the preliminary phase of any design intervention for an historic building.

Therefore, having all the information needed is a fundamental step in the design process. The Excel shared parameter schedules were filled in accordingly with the design phase and all the data were imported in the BIM model.

Dynamo Player provides a simple way to execute Dynamo scripts in Revit. It displays a list of Dynamo scripts in a specified directory, along with the current status of each script giving the possibility to open and modify it.

To make Dynamo scripts more adaptable and user-friendly, using Dynamo Player, it is possible to design user input and output to be assigned before running the script. Once the input data are defined, the script will run by clicking on play and it will be possible to check immediately its success by the output data.

After having run all the scripts and exported the IFC file with the specific Pset it is possible to import it in the energy analyses software Termolog. The BEM model is enriched with the right thermal transmittance values, for both stratigraphic element and windows. In the pictures it is possible to see the difference between the values imported by the standard IFC (figure 3) and the implemented one (figure

4). This discrepancy could lead to significant errors during the design phase. It is possible to see that the *.ifc file without the material thermal properties implementation is imported with default values for conductivity, mass density and specific heat; this leads the software to calculate incorrect values for thermal resistance and thermal transmittance of the elements.
All the other information are available on the IFC file that can be open directly from the Termolog interface (figure 5).

	Strati	Spessore [mm]	R [m²·K/W]	λ [W/m·K]	ρ [kg/m³]	C [kJ/kg·K]
	Adduttanza interna (flusso orizzontale)		0.130	7.690		1.000
A	Plaster-externalWall	15.0	0.015	1.000	1 000.000	1.000
B	Brick(external), Common	420.0	0.420	1.000	1 000.000	1.000
C	Plaster-externalWall	15.0	0.015	1.000	1 000.000	1.000
	Adduttanza esterna (flusso orizzontale)		0.040	25.000		1.000

(a)

Struttura	Codice	Tipo	Vers...	S	A	U/ψ	C	Uso
Pareti								
IFC								
Muro di base:Generic - 150mm Brick	pa0006	Parete	Esterno	18.0	-	2.857	54.600	44.70
Muro di base:Generic - 160mm Brick	pa0017	Parete	Esterno	16.0	-	3.030	49.863	23.26
Muro di base:Generic - 450mm Brick	pa0003	Parete	Esterno	45.0	-	1.613	66.496	377.82
Muro di base:Generic - 450mm Brick 2	pa0007	Parete	Esterno	45.0	-	1.613	66.496	167.00
Muro di base:Generic - 500mm Brick	pa0001	Parete	Esterno	45.0	-	1.613	66.496	410.68

(b)

Figure 3. (a) Thermal properties imported for masonry: "Muro di base: Generic – 450mm Brick" by default. (b) Incorrect transmittance values to analyse the building envelope

	Strati	Spessore [mm]	R [m²·K/W]	λ [W/m·K]	ρ [kg/m³]	C [kJ/kg·K]
	Adduttanza interna (flusso orizzontale)		0.130	7.690		1.000
A	Plaster-externalWall	15.0	0.021	0.700	1 440.000	1.000
B	Brick(external), Common	420.0	0.778	0.540	1 200.000	1.000
C	Plaster-externalWall	15.0	0.021	0.700	1 440.000	1.000
	Adduttanza esterna (flusso orizzontale)		0.040	25.000		1.000

(a)

Struttura	Codice	Tipo	Vers...	S	A	U/ψ	C	Uso
Pareti								
IFC								
Muro di base:Generic - 150mm Brick	pa0006	Parete	Esterno	18.0	-	2.092	63.547	44.70
Muro di base:Generic - 160mm Brick	pa0017	Parete	Esterno	16.0	-	2.204	58.978	23.26
Muro di base:Generic - 450mm Brick	pa0003	Parete	Esterno	45.0	-	1.009	56.898	377.82
Muro di base:Generic - 450mm Brick 2	pa0007	Parete	Esterno	45.0	-	1.009	56.898	167.00
Muro di base:Generic - 500mm Brick	pa0001	Parete	Esterno	45.0	-	1.009	56.898	410.68

(b)

Figure 4. (a)Correct thermal properties imported for masonry: "Muro di base: Generic – 450mm Brick" using the developed workflow. (b)Correct transmittance values to analyse the building envelope

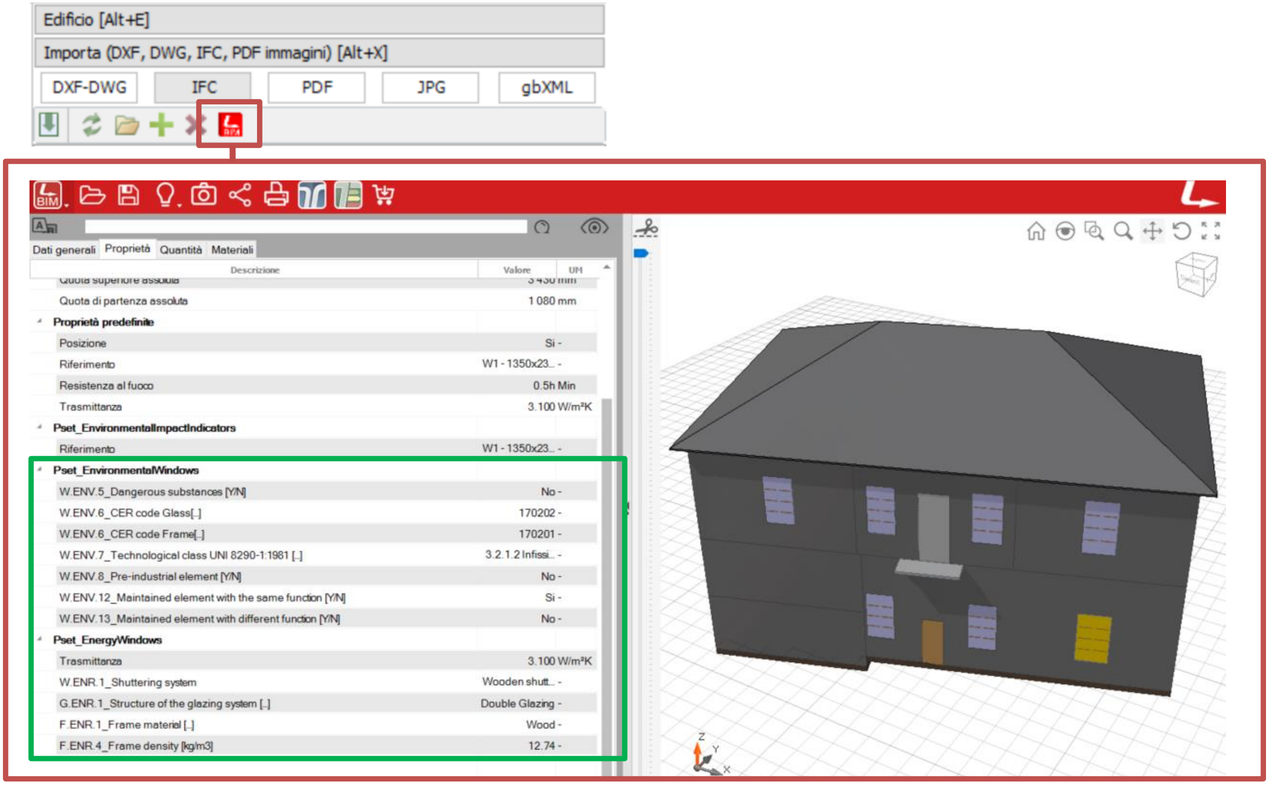

Figure 5. Information available in IFC file that can be viewed in Termolog interface.

6. Discussion

The application of this methodology to the energy discipline, even if limited to the building envelope, made it possible to specifically determine the necessary information and draw a guide towards defining its Level Of Information Need. Having a concrete and real vision of the information needed from the beginning of the design is essential to avoid wasting time and future errors.

The improved effective interoperability between Revit and Termolog is certainly a fundamental aspect of this research, but it is also interesting to note that a correct and organized transmission of data is an important result. Making the data more easily accessible, without having to use a BIM authoring software for their reading, but being able to consult them through an IFC file or Excel tables, lighter and more manageable files, allows to streamline the workflow and reduce machine run times, especially in the case of large buildings with very heavy models.

The use of Dynamo Player makes this method usable even by professionals with little experience of visual programming language and makes it easily replicable to other projects; by inserting the respective inputs, all the information flow can be used on any BIM model. From the very first steps the idea of creating a tool that could be replicated and easily reused by other professionals was a fundamental objective of the study.

The creation of a common customized library and the application of the dynamo script for the acquisition of this information in the IFC format, leads to use more precise data and greater precision in the analyses.

This argument has a greater validation for historic buildings, in fact, in this area, particular attention must be paid to the properties of the materials: their use over the years may have altered the properties that will therefore no longer be those present in the standard schedules or in the manufacturers' technical data sheets. The possibility to enter the correct properties right away, without having to rewrite them within the energy software, leads to greater execution speed and greater accuracy of the analyses.

7. Conclusions

Future developments starting from this study could be varied, beginning with the application of the entire workflow to other disciplines. The versatility and replicability of the method allows to hypothesize its use also for different disciplines, as data transfer is a problem that affects all disciplines involved in design.

This research could be a stimulus for software companies to develop their interfaces according to the Level Of Information Need and to integrate their interoperability skill to offer more useful tools to the designers. The software used in this study can be just an example, it will be possible to develop the same workflow using others; the VPL language can be used on other BIM authoring software, like Archicad (Via Rhino and Grasshopper), and the IFC standard allows to import the model in other BEM software. For this study was considered Termolog because is a software approved by CTI (Comitato Termotecnico Italiano), which is a UNI federated body that gives regulatory support on laws and regulations energy thermal-energy related and collaborate to draft CEN and ISO standards. For this reason was considered more appropriate to conduct a study on an historic building that respond to the national laws and standard.

It would be very interesting to continue with the analysis of the information flow beyond the preliminary analysis phase and to study methods to make the information exchange more efficient during the design phase. In particular, it would be interesting to understand how to approach the reverse process, from BEM to BIM, once the analysis is finished, in order to create the BIM and IFC file with the final information to share with other professionals and the client. It is also interesting to extend the discussion not only to the building envelope, but also to its analysis of the systems, lighting technology and all the other information necessary to create a sustainable, low-consumption project with adequate internal comfort.

This study is therefore another step that approaches the goal of greater interoperability between software, which joins the overview of current works and leaves room for the development of future research.

8. Reference

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