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Towards a Parsimonious Information Management for Energy Retrofitting of Buildings

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Abstract

Throughout the world there are thousands of residential and public buildings that have been built during the reconstruction and rapid urbanization after the 2nd world war, particularly Eastern and Central Europe as well as in China. These are the most efficient target for mass improvement of their energy use through the improvements of façade insulation and windows. Advanced information technology (IT) - including building information modelling technology (BIM) - is not used very often in these renovations. Our hypothesis is that the use of BIM could be more efficient if it would focus on the essential information needs of the actors involved. The key idea of BIM - structured collaborative shared database of all required information - should be preserved but the model should be parsimonious. The paper presents the ongoing research in the context of a bilateral Chinese-Slovenian project with the goal of designing parsimonious information management for the retrofitting of existing buildings. The broader goal of the work is to study information modelling supporting works where a complete information model may not be needed at all and where a detail process definition - as outlined in BIM execution plan and related documents - would lead to overspecification, constraining the workflow.

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Keywords: building information modeling; energy efficiency; renovation; building process; parsimonious;

1. Introduction

Buildings are a major (up to 40%) user of primary energy everywhere in the world. Unlike with cars or electrical appliances - where the next generation can be more energy efficient than the previous one - buildings have a life span of decades or even centuries. The only way to improve the energy efficiency of the buildings is renovation. This is a goal in national strategies of both China and Slovenia (Smart Specialization). It is expected to make a major contribution in tacking climate change.

1.1. Renovation of buildings

In Europe, China and in many other countries in the world, there has been a serious housing crisis following the baby boom years after the Second World War. The crisis was being solved by a rapid construction of high-rise apartment towers and blocks. They were being built rapidly and economically, with several copies of each design, and in a time when energy was cheap. Such buildings can be seen at the outskirts of all major European and Chinese towns. The

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problem of those buildings today is that they are very energy inefficient, but also a grey and boring relics of some times gone by.

Since climate change issues got focus, massive renovation programs have been set in motion across the world. The main contribution would be the improvement of the façade, both optically as well as aesthetically. In the meantime, Building Information Modelling (BIM) technology has matured, which is driving renovations in the building field in recent years.

1.2. Building information modelling

BIM is an approach to building design and construction planning where a detailed, semantic, digital model of the new building is created collaboratively and shared to everyone involved in the construction process. Standards have been developed and implemented for the information structures and representation language of building information models. ISO 16739:2013 specifies a conceptual data schema and an exchange file format for BIM.

Because more and better information exists than can be captured in drawings, the designs can be better, more consistent, with fewer mistakes and surprises on the construction site. By conservatives estimates this reduced the price of construction by at least 10%, more liberal estimates are beyond the 20%.

BIM technology so far has (1) mostly been used for new construction, (2) research has been focusing on the digital model and (3) the conviction was that this model must be as complete and realistic as possible.

1.3. Research objective

The objective is to study how the BIM approach could be used in cases where the construction in question is not a new construction, where just some limited subset of information about the building is actually required and where the related process is repetitive. An example of such topic is energy renovation of buildings. Just a limited set of information is needed, several identical of similar buildings exist and the processes are repetitive.

Specific tasks include:

- Review how information technology, particularly the BIM approach is used for renovation, specifically for energy-efficiency renovation.
- Study of the renovation process and its information needs. We study how the process is performed, what is the knowledge base related to energy efficiency renovation, what are its information needs and how the process can be reused from a building to a building and from a renovation to a renovation. At some level of abstraction all processes are the same which introduces repeatability into the construction industry which is otherwise known for handling unique products (buildings) built in unique construction processes. This is unlike other industries where serial production is the norm.
- Develop a parsimonious subset of the building information model and not strive for an as-realistic- and as-complete-as possible information model. Models require effort for all the information to be compiled, however, the bulk of that information may not be needed in the downstream processes. In spite of not striving for a complete BIM model we will investigate how to use ISO standards and, if need is discovered, propose how standards should be extended for the representation of incomplete information needed for energy renovation.

2. Technologies for Computer Aided Energy Renovation

Information technology is used extensively in renovation projects. The list of technologies includes:

- GIS - Geographic Information Systems - they are used to store geographic and geospatial information in layers so that the spatial information can be created, stored, manipulated, analyzed, visualized and linked to

the project. Besides the exact location and location information (such as coordinates and the shape of the terrain, satellite images etc.) it also connects to the municipality databases in order to present administrative constraints regarding the desired renovation from the building as well as location perspective.

- Laser scanning and remote sensing - these technologies are usually the quickest and the most accurate step towards digitalization of physical objects. They are used to accurately capture inaccurate boundaries of the buildings (residential, nonresidential), which is especially valuable for the historic buildings without accurate plans or building permit documentation. Even with documentation it is often used to capture object as-is as opposed to the as-should-be reality of the AEC project documentation.
- Accumulative and solid modelling - is a technology (it can also be presented as a set of principles) for (computer) engineering of 3D models (solids) as a presentation of (physical) objects. As it is typically used throughout the whole project design lifecycle, in the context of renovation, it is usually the successor of laser scanning and the logical and necessary step in the process of scan-to-BIM, resulting in the foundation for BIM.
- BIM - Building information models, modelling and management. It is well known and was discussed briefly in Section 1.
- Computational fluid dynamics (CFD). CFD is used for the detailed analysis of the indoor climate in buildings for the evaluation of the performance of the HVAC systems, the prediction of thermal comfort conditions and the design of special purpose ventilation, heating and cooling systems according to the geometrical design of the building (building orientation, openings, glazing surfaces etc.). CFD simulations are especially important for the restoration of buildings and can be used for two important purposes: 1) to explain what was happening before the renovation and therefore identify problems in initial design, and 2) to validate the improved and refurbished design.
- High-throughput computing (HTC, for simulations) and cloud computing (for HPC, CDE). Both HTC and HPC are used for the time and power intensive tasks in order to obtain, analyze and validate results in the reasonable time frame. While HTC is aimed at tasks which can be parallelized, HPC is promoting and speeding up all other duties. Both of them are an important enabler of the use of CFD technologies in AEC as those analyses are otherwise too time consuming.

The technologies have been listed roughly in the order in which they are used.

3. Renovation processes

Renovation processes have been studied in greater detail by several research teams and they are also taking place in the practice.

In the TES project (Cronhjort, 2009) the renovation process has been broken into the following phases: building examination - digital measurement - planning - off-site fabrication - on-site assembly. The approach used pre-fabricated elements to attach to whole or large areas of façade which called for a rather detailed model of the outside of the building. The project is implicitly aware of the tradeoff between BIM complexity and renovation requirements.

BIM technology is taken for granted as a welcomed tool in renovation projects. Yin (2010) claimed that BIM plays important roles in the energy & cost savings of the building's life, particularly in the stage of building management - it enables simulations in the building's digital twin.

Di Mascio and Wang (2013) claimed that particularly Building Information Modeling (BIM), makes the design, organization and construction of renovation projects manageable and improve them. They see benefits in three dimensions of sustainability, environmental impact, and economical and social benefit.

Aldanondo et al. (2014) addressed the problem of industrialization of energy renovation of apartment buildings. It limits the BIM information needs to the external dimensions of the building and it also finds the need to project to the outside envelope some structural characteristics of the building. The paper (ibid.) presents an implicit ontology that is useful as a point of departure for our work. It defines a renovation process that has five stages: building geometry generation, building analysis requirements characteristics, renovation specific design, manufacturing of pre-made

components and renovation on the building site. It differs from our work in the fact that it deals with prefabricated elements for the improvements of building characteristics.

Hammond et al. (2014) studied how professionals use BIM in retrofitting and renovation and how it affects their practice. They investigated a renovation process that had the goal of utilizing BIM "in as many areas as possible" with a view to comply with LEED rating system. They found that the information sharing and collaboration features of BIM made it a great tool for the renovation of existing buildings, regardless of the scope of the renovation. Also useful was energy simulation and conflict resolution. It can be assumed that a rather thin BIM model suffices for that, however, the work did not focus on establishing a standard model or process.

Khaddaj and Srour (2016) defined a renovation process with three stages: pre-energy modelling stage, energy modeling stage and refurbishment options stage. They identify challenges related to the use of BIM for renovation: multi-disciplinary nature of participants, the timeliness of the exchanges, and the wide array of technologies. In the research agenda, they pointed out that both Information Delivery Manual (IDM) and Model View Definition (MVD) focus on new construction and not existing buildings. Construction Operations Building information exchange (COBie) standard does not include architectural and structural components that could be relevant for refurbishment. They concluded that "BIM is still immature for its full adoption in refurbishment projects because of technical, informational and organizational complications". Our parsimonious approach should be addressing these complications.

Scherer and Katranuschkov (2018) coined the word "BIMification" for a process where BIM technology is used extensively in the design and implementation of the renovation processes. They propose a structured approach for the creation of a BIM model of existing buildings to be used in retrofitting. The renovation process is split into anamnesis (collection of data about the building), diagnosis (analysis and interpretation of the collected data) and therapy (designing and implementing the retrofit). As the approach is generic it creates a rather complex, thick BIM model which, in our view contains more data than needed for our class of buildings.

4. Lessons learned so far

The issues have been studied in ISES project. This was a H2020 project from EU FP7 running from 2011 to 2014. ISES was developing ICT building blocks to integrate and complement existing tools for design and operation management into a Virtual Energy Lab capable of evaluating, simulating and optimizing the energy efficiency of products and facilities, in particular components for buildings and facilities, before their realization and taking into account their stochastic life-cycle nature (see Figure 1).

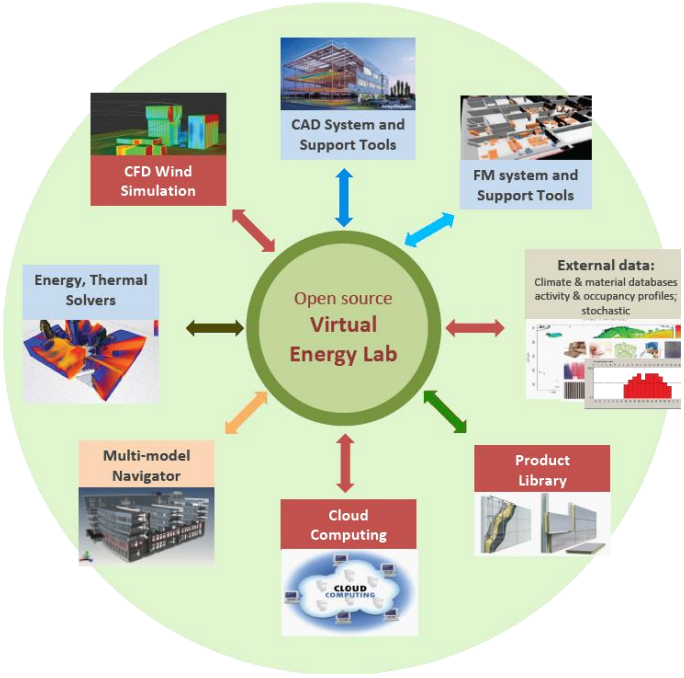

Fig. 1. ISES Virtual Energy Lab.

Among the results of the project was also the energy-aware decision workflow starting early in the design phase affecting the energy performance of the building being validated with powerful cloud-based services using developed pre- and post-processing tools. All of them were consolidated into extensible open-source virtual lab kernel.

Nevertheless, the project showed that that are a lot of challenges when performing design analyses. While some of them are considerably less severe nowadays as they were in 2014 (such as shortage of BIM experts or lack of BIM and other relevant standards on national and world levels) there are still issues that have yet to be resolved. A lot of them are related to the essence of BIM and what BIM actually is to a project group. ISES project showed that not all BIM models can be used for every analysis and in any stage of the project/project design. While there were parts of the model that were mostly not detailed enough (such as HVAC which usually lacked important attributes), models for the most part were too detailed, complicating analyses and resulting in non-converging CFD equations, time-consuming processes and unusable results.

The ISES project showed that there is a need for a reusable BIM solutions for repeated projects tasks, one of the most important ones being a transition from architectural to (simplified) energy-specific model views.

Initial studies of the process and information analysis have been performed by a few master theses at the University of Ljubljana. At one side of the spectrum is the work by Todorović (2009) who created a detailed BIM model for the renovation of a building. On the other hand, Radošević (2015) was finding simplified SkectUp geometry of the buildings sufficient for the insulation, shading and energy requirements estimates. Quantity and costs estimate for a particular building have been established through the use of software by a particular insulation material manufacturer. This software is not general-purpose BIM modeller but specialized software that lacks several features of BIM. However, its information needs are a very good example of what information is indeed needed for renovation with particular technology. Stamač (2017) performed a renovation of a typical building targeted in this project and his analysis revealed that a rather limited set of data is required to do the analysis. That work too presents a good context for the study of information needs.

5. Conclusions, discussions and future work

We have presented the motivation, goals and points of departure for a Chinese-Slovenian project that should allow for industrialized renovation of residential buildings using BIM concepts and technology. Literature study and previous

work show that the information requirements for energy renovation and very different than for new construction and so is the process itself.

Further work in the project will be focused on the following. (1) study the documentation of existing renovation projects, their information needs for analysis and the design and renovation process, (2) perform a survey in the industry that is involved with renovations, particularly related to decision making in design and renovation, (3) propose an information model that would address the needs established in 1 and 2 and match it against standards and applications including IFC, BIM modellers, IDM and COBIE, (4) establish a generic process model that would serve as a guide for industrialized construction, (5) test 3 and 4 in a real project, (6) study general lessons about the use of BIM approach, BIM technology, BIM collaboration in a setting that requires partial, simple, or parsimonious product and process models.

Acknowledgements

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