EMPLYING BIM FOR THE OPTIMIZATION OF ENERGY EFFICIENCY IN RENOVATION PROJECTS: EITRE CASE STUDY

Ola ALHAJ HASAN
IUT Bethune, Laboratory of Civil Engineering and geo-Environment (LGCGe) EA(4515)

Stephan KESTELOOT
IUT Bethune, Laboratory of Civil Engineering and geo-Environment (LGCGe) EA(4515)

Didier DEFER
Faculty of Applied science, Laboratory of Civil Engineering and geo-Environment (LGCGe) EA(4515)

Daniel AMMEUX
IUT Bethune

Abstract—Incorporating energy efficiency is nowadays the top priority of building renovation projects. The renovation solutions are normally the result of many combined solutions concerning all components of the building (walls, roofs, windows, doors, HVAC, occupation...) and the final outcome is the sum of these micro solutions. The modeling and simulation of the building thermal behavior can quickly become a very complicated and time consuming task with so many variables and factors to be considered. Moreover, the lack of data and ‘up to date’ plans of old buildings can complicate the mission and retard the conception phase. Thus, a high need of easy modeling and simulation tools and procedures is an essential success element for this kind of projects. This obviously is not provided by the traditional modeling and simulation tools. Here appears the high potential of the Building Information Modeling concept which allows project teams to easily bring together data to build the base model and then test different patterns of solutions within very reasonable delays. This paper uses the BIM concept and many of its tools in order to compare different renovation scenarios and check their outcome effect on the building energy efficiency represented by the building energy consumption and users' thermal comfort. The aim is to employ BIM to integrate the energy efficiency needs early in the conception phase of any renovation project.

I. INTRODUCTION

Building energy consumption is nowadays one of the most important challenges in France [1], [2]. Taking into account the increasing energy prices and the decreasing energy resources, the energy efficiency is becoming a major research field to reduce the consumption without affecting the users’ comfort [3], [4]. As a first step, the energy efficiency as well as the environmental impact of a building have to be taken into consideration early in the conception phase [5]. However, a big part of buildings in France has been built before the rising of the efficiency problem and thus these buildings are not necessarily energy efficient.

Literature study shows that the main factors to judge the building energy efficiency are [6], [7]:

1. The building envelope (construction) [8], [9], [10].
2. The heating system [11], [12], [13].
3. Users’ behavior [14], [15].

Many studies and works focused on the building envelope as a main key of improving the building thermal behavior. Moreover, many construction materials and technologies have been developed to optimize this behavior. However, the main challenge has always been the prediction of this behavior with the traditional energy simulation tools. Thermal simulation has always been a key element in the prediction of the thermal behavior of a building [16]. With the high number of parameters that affect this behavior, the simulation can quickly become very complicated and time consuming. Nevertheless, given the fast improvement of both technical and processing tools, building modeling has been one of the fast changing domains and many concepts and tools have been developed concerning it. The main concept that appeared in the last 30 years is the concept of Building Information Modeling ‘BIM’[17]. BIM can be considered as an interactive database where all the components are related and all the information is stored in one file. This revolution led to the possibility of bringing together all type of sources, materials, equipments and scenarios without much effort in order to have an overall model shared between all the stakeholders. Afterwards, executing any type of simulation (structural, thermal, lightening,...) can be easily done without ignoring any factor. In this paper, the possibility of improving the building energy efficiency using the concept of BIM is explored by the application of this concept starting from the conception phase in a renovation project.

II. BIM CONCEPT

A. Advantages over traditional tools

As mentioned above, the main advantage of the ‘BIM’ concept is the possibility to provide a comprehensive and interactive platform that is easy to employ and modify without any time taking procedures. It also promotes the coherence and consistency of all the information dispatched in different software and documents which reduces the probability of errors or conflicts between all the stakeholders of the project.

Concerning renovation projects, BIM has two major advantages regarding the project documentation and renovation scenarios [18],[19], [20]:

1. Concerning the project documentation, as in most renovation projects, the lack of information and plans of the buildings is a major problem that can be very expensive and time consuming to rebuild. Moreover, for old buildings which have been the subject of many reforms or changes over the years, even in the case of available plans, these are not necessarily reflecting the actual state of the building. Here appears the advantage of BIM tools by an easier reproduction of any missing information. This point will be more developed and explained in the next section.

2. Concerning the renovation scenarios, BIM provides the possibility of testing and validating several scenarios before choosing the most advantageous one that respects the predefined limitations and conditions. This scenario testing procedure is easy and fast to apply unlike the traditional simulation tools.

B. BIM main tools

Building information modeling is a concept that has been enriched by many tools and software designed to be ‘BIM’ compatible. These tools start from high technology 3D scanners to all types of software. For our ‘energy oriented’ Study for a renovation project, we chose to use the following tools in order to conduct our research:

- 3D scanning device: This device will provide a ‘point cloud’ of the building with all geometric and architectural details.
- A 3D building design software: This (CAD) software helps tracing the point cloud to build a 3D model which contains all the architectural and structural details. This 3D model will be shared between all the stakeholders in order to add every single detail on it. The software used in our case is Revit from Autodesk.
- A dynamic thermal simulation software: As the main objective of this work is
improving the energy efficiency, an energy software had to be used to realize all the dynamic-thermal simulation. The software used in this research is Confibie Pleiades.

- A thermal regulation software: This software is needed to check the complicity of the building with the regulations in France. The software used in this study is Archiwizard. This is one of the certified software by the french thermal regulations (RT2012).

While the thermal simulation software was used mainly to reflect the thermal behavior of the building over time and thus allow a check of users’ thermal comfort taking into consideration factors as the weather, the sun radiation, the occupation scenarios and the heating systems etc, the thermal regulation software is a tool used only to check if the building complies to the regulations in action or not according to the performance of its envelope and its energy consumption taking into consideration its geographical location and its use.

Figure 1 shows the steps proposed to employ the BIM concept in this research. The big advantage of using these tools is the simple juggling of the 3D model between them without any need to retrace it each time oppositely to old traditional tools.

![Fig. 1. The proposed steps of the rev](image)

This simulation procedure allows employing a whole building process taking into consideration all factors rather than applying one or more isolated design guidelines [21]. For this research, a check of several renovation scenarios of only 2 components of the building (north oriented windows and wall insulation) will be done in order to choose the best combination of solutions according to the fixed priorities and requirements. The choice of only testing 2 components comes from our priority of demonstrating the easy process rather than effectively find a global solution which is the goal of an ongoing research.

### III. CASE STUDY

This work has been done under the project ‘EITRE’ (Inte- grated Eco-system for the Energetic Transition and Rehabilitation) which is dedicated to the renovation and sustainability of the building IUT (the Technology Institute of the University) located in Bethune city in the north of France. In fact, most of the technology institutes in France were built in the 70\(^\text{th}\) s. As a result of the ‘BabyBoom’ after the second world war, a fast building was needed to cover the sudden high number of students. That is why a pre-constructed solution was the most adapted type of construction. Most of these buildings had similar architecture. The project EITRE is then playing the role of a pilot project for many semi-identical buildings situated all over France. Figure 2 shows the location of the concerned buildings. For this research, a study for only one building (Building of civil engineering department) is done (the highlighted south oriented building). The building of civil engineering is a 3 storey building with the components shown in table I

#### A. Phase 1: Requirement definition

As explained before, the main objective of this study is employing the BIM tools to test several renovation scenarios and choose the most advantageous one in terms of energy efficiency. An energy efficient design process begins with assessing the occupant’s needs and a budget study [21]. For our study, the main priorities fixed for the energy efficient renovation project are:
Comfort estimation: a quantification of the comfort was done using the concept of 90% and 80% satisfaction proposed in ASHRAE [22]. The percentage of time where the temperature is in the 90% acceptability range was calculated for each proposed simulation. The scenarios are then classified according to this criteria.

- The annual energy consumption
- The respect of the thermal regulations applied in France.

There are three main requirements to respect in the thermal regulations in France:
1. The maximum allowed Bio-climatic energy needs (Bbio).
2. The maximum allowed primary energy consumption.
3. The summer comfort.
4. These three factors are illustrated in figure 3. For information about the calculation of these three elements according to the input shown in figure 3, consult the thermal regulations in France (RT2012)[23]. In this paper, the primary consumption is not calculated as we chose to concentrate on the building envelope and not the heating system for this part of the research.

B. Phase 2: 3D Modeling phase

In order to start our thermal and energy study, a 3D model is needed to implement in the energy simulation. As the building is more than 45 years old, the available plans are no more up to date and a reproduction of plans is needed. That is why a 3D scanner was used as a first step of plans production. As mentioned before, the 3D scanner produces a so-called ‘Point cloud’ precision enough to reflect all architectural and geometric details of the building both from the inside and the outside (a maximum scanning error of +0.004m related to the equipment). Figures 4 and 5 show the obtained point cloud and 3D model of the building. After scanning the building and importing the point cloud to a 3D modeling tool (Revit in our case), a simple tracing is enough to create the 3D model. All dimensions are then defined and a material definition is integrated in the model with information obtained through either the old available documents or a core drilling process. The scanning step for the building took 1 day of work while the Revit tracing process with all the preparation of the BIM database can take around 3 working days.
The main three losses are actually happening through exterior walls, roof and thermal bridges respectively. As for the roof, we will not take it into consideration in the studied renovation scenarios as we are considering so many combined scenarios for it including renewable and green roof solutions. However, in scenario 13, an isolation of the roof is proposed in order to justify our choice of not including the roof in the traditional solutions. On the other hand, as for the losses through walls, the detailed results show a big percentage of losses due to the north facade (too many windows and related thermal bridges). So for this paper, 13 combinations of renovation scenarios concerning only the two following components of the building are presented:

- Thermal insulation for walls (‘Laine de mouton’ is studied in this article);
- Number of north oriented windows.

The choice of these scenarios is done according to the first reflection on the actual state that was mainly oriented towards blaming the bad insulation of vertical walls and the north oriented windows on the energy losses. Table II give a re-capitulative of the proposed scenarios.

This paper is a first step to accomplish a data base with all the possible and adapted scenarios of renovation that will be later manipulated using a data mining tool in order to choose the best scenario of renovation through a ‘BIM- data mining’ combination assistance.

D. Phase 4: Dynamic thermal simulation for comfort conditions

After the 3D modeling phase, the model is imported to the dynamic thermal simulation software which is connected to weather databases in order to simulate the building dynamic thermal behavior and check the comfort condition allover the year. In order to do this, a thermal zoning is done first as
E. Phase 5: Thermal simulation for regulations check

After the validation of the thermal comfort condition, a final check of the complicity with the regulations is done. This phase is accomplished using the software Archiwizard (Figure 8).

These 5 phases have been applied on the mentioned 13 renovation scenarios and the results varied from one scenario to another. A comparison is then achieved using 5 main criteria: The heating needs, the lightning needs, the bio-climatic needs (Bbio), the number of hours of summer discomfort per year and the percentage of discomfort according to the 90% satisfaction rule of Ashrae. Figure 9 shows the comparison between all the 13 scenarios according to the base model (actual state). The outer gray line of the graphs represents the values of the actual state (base line model)(note that in case 13 it is the inner gray line).

The results of the comparison are a mix of results from Revit modeling, Comfie simulations, Archiwizard simulations and a matlab algorithm to calculate the winter thermal comfort percentage. From the figure, it is obvious that in most cases there are no significant differences in the behavior no matter how deep is the wall insulation or the number of windows eliminated on the north wall. However, as the renovation concerns only two components out of many others, the results are not necessarily significant and the accumulation of
these results with other components solutions might give interesting scenarios.

Taking the example of scenarios 6, in fact the effect of 20 cm of insulation is obvious concerning the reduction of the heating needs and the Bbio value, on the other hand this insulation leads to a worse summer comfort. Another example is scenario 8, as in 6, the heating needs as well as the Bbio value actually decrease thanks to the insulation. However, eliminating 75% of north oriented windows also affects the lightning needs which become more important. And in spite of these modifications, the summer comfort is not affected. For scenario 13, a huge difference in the needs occurs when we add roof insulation.

From the achieved comparison it is obvious that the most common solutions are not necessarily the most advantageous solutions. In our case, insulating the walls and eliminating the north oriented windows doesn’t cause a significant reduction in the energy consumption. A further look on the surfaces shows that the roof has the biggest exterior surface. That is why its insulation can change dramatically the situation. On the other hand, the comfort is also a main player that has to be taken into consideration. A high insulation would cause probably a discomfort case especially in summer (scenario 13). So more renovation combinations are to be studied considering the roof and all other components of the building in order to find the best compromise between the selection criteria.

This part of the research studied only 13 renovation scenarios to demonstrate the facility of doing the simulations using BIM tools and the possibility to easily achieve and compare different scenarios, a luxury that was not available with the traditional simulation methods.

The optimal solution is not mentioned or studied here especially that the study took into consideration only two components of the building out of many others. The studied scenarios can obviously easily overwhelm any traditional simulation or modeling tools with the high number of variables and information they include. This is another advantage of the BIM concept of stocking all the data and the variables in interactive databases which are auto-updated and available for all stakeholders at any point of the project life cycle.

IV. CONCLUSION AND FUTURE WORKS

From the past section, we can conclude that the new BIM concept and its tools have dramatically reduced the complexity of running simulations and creating models as well as the time spent doing this.
This is mainly because of the collaborative concept and the easy juggling between the different tools. This concept main advantage is then not only the collaborative work but also the possibility to test and choose between different solutions without spending a lot of time creating the models for each one. This is mainly interesting because of the potential of testing all possibilities and their impact on the energy efficiency before making a decision on the final renovation scenario.

The second big advantage is the auto-construction of an interactive data base shared between all the stakeholders and available for the project whole lifecycle.

In this part of research we limited the tested solutions to 13 in order to focus on the methodology of work and the utility of the tool rather than the solution itself. For the next step, a generation of a data base by BIM tools together with a decision algorithm between the different elements of solutions (more scenarios concerning all components as well as different materials) is being developed using the concept of data mining. The coupling of these two concepts: ‘BIM’ and ‘Data mining’ might form a big step towards the future renovation solutions to choose the best patterns over the classical common solutions of renovation that are not necessarily adapted to all cases and types of buildings.

REFERENCES

[15] G. Ye, C. Yang, Y. Chen, and Y. Li, “A new approach for measuring predicted mean vote (pmv) and standard effective temperature (set),”


