Sustainable retrofit based on BIM

Laura do Carmo Baumgratz de Paula Larivoir

Federal University of Rio de Janeiro, Department of Urban Engineering, Rio de Janeiro (RJ), Brazil
lauracbpaula@poli.ufrj.br

ABSTRACT: The construction industry is responsible for a significant amount of environmental impacts, which mostly are due from the phases of use and maintenance. Rehabilitation of buildings in Brazil is an opportunity of solution for the large number of buildings that have obsolete structures and/or outdated equipment. In this context, BIM allows you to analyze various dimensions of the building, while considering different sustainability parameters. This work aims to contribute to the integration of sustainable retrofit theme in Brazilian society, so that there is greater awareness of the importance of the issue, and enable a more eco-efficient analysis with the use of BIM systems. A literature review was made and the main concepts of sustainability in construction, sustainable retrofit and green BIM were related. Two study cases were analyzed using the Revit tool and the advantages and difficulties encountered in the use of BIM were listed. The main advantages of using BIM for green retrofit include: the establishment of enterprise database for future interventions and maintenance, analysis of projects over the life cycle of the buildings, and consistent modeling allowing results close to reality. This work can contribute to a greater understanding of what is sustainable retrofit and how it can be accomplished used BIM, helping project teams in decision-making.

Keywords *Retrofit; Sustainability; BIM.*

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1. INTRODUCTION

Currently more than half the world's population lives in cities, most in conurbations with over one million inhabitants. People spend 80% of their time in buildings and most of the time remaining in polluted urban areas. The sedentary population, far from nature, demands more and more internal space for their comfort (Edwards, 2008). The process of urbanization of cities had an important reflection on economic development and increasing the life expectancy of the population. On the other hand, cities that were once synonymous of better living conditions, today face serious problems such as pollution, the deterioration of the urban environment and increased poverty. According to Farr (2013 p. 94):

" The modern consumer society (...) explores the natural resources at a rate that the Earth cannot support. Our appetite for oil, electricity, mobility, internal spaces and material goods is huge and unceasing. A clear international scientific consensus confirms that the past few generations since the oil era, the resulting population growth and increasing per capita impact of human activities have changed the Earth's climate."

The World Congress of Civil Construction (CIB) in 1998 elaborated the Agenda 21 on sustainable construction, and defined sustainable construction as "holistic process to restore and maintain harmony between the natural and built environments and create institutions to confirm human dignity and encourage economic equality "(Morettini, 2012).

According to Motta (2009), to find sustainable development we must act in three dimensions: environmental, socio-cultural and economic, through actions "environmentally responsible, socially just and economically viable."

In order to make cities more sustainable there are different scales of intervention: from the reduction of energy consumption of buildings to increasing urban density. In this context, the retrofit of buildings appears as a possibility of application of the developed concepts of sustainability, which are often only in theory. When performing the retrofit of an existing building, there is a cutback on the impact of a new building, whether sustainable or not. It avoids the demolition, which generates a huge amount of waste, there is a better use of facilities, a reduction on the consumption of materials and on the derived carbon emissions from transport and construction, increasing the life of the building, maintaining the existing embodied energy in the building, saving energy through the adequacy of buildings to the new parameters of energy performance, improving indoor environmental quality and reducing water consumption. Note that to actually have a sustainable building the social factor is essential, occupants should be aware of its importance before the degradation to the natural environment, and have attitudes consistent with the sustainability values applied in the design phase and execution.

Due to its characteristics, BIM is able to impact on the three pillars of sustainability. From an economic point of view, it is possible to reduce project costs, improving information management and enhance coordination, with the result that fewer resources are wasted. In the social aspect, tools based on BIM facilitate the analysis and simulation of different parameters (that with traditional tools would be very complicated and would require manual data entry) allowing complex analyzes (such as daylight), and creating better

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conditions of work and life, increasing comfort and well being. Regarding environmental aspects, BIM supports a number of environmental performance analysis but to optimize their abilities is required the integration with other special tools, such as LCA (Antón, 2014). For Machado (2015), research with tools that enable integration between BIM and LCA can contribute significantly in the implementation of both in the construction industry, qualitatively influencing the decision-making.

Although BIM and sustainable construction are not new concepts in the architecture and construction industry, its potential for integration has been recently explored, still having few studies that demonstrate how BIM can assist in sustainable building practices. In order to achieve a truly sustainable design its essential the integration between all building systems. BIM has in its inherent nature the possibility of integrating all areas of construction, and to achieve a sustainable world it is at the front end of a project for the design, construction, operation and maintenance (Hammond, 2011).

1.1 RETROFIT

Retrofit can be defined as interventions in the building in order to adapt it technologically, which differs substantially from the restoration, which consists in refund the property to its original condition or reform, which aims to introduce improvements without commitment to its previous features (Guimarães, 2014). Retrofitting reconciles certain striking features of the building with its technological adaptation.

Limited natural resources, high costs of space and construction, lack of availability of land made necessary interventions in existing buildings, making them more energy efficient (Chunduri, 2014). Another factor that has led to retrofit is the rehabilitation of central areas in cities such as Rio de Janeiro, Sao Paulo and Belo Horizonte, which were degrading due to dynamic real estate market.

Among the main advantages of a sustainable retrofit are reducing environmental impacts, increased profitability and minimizing operational costs. According to Wong (2015), the greenbuildings have a reduction in the cost of operation 14% and an increase of 11% on the market price when compared to traditional buildings.

Several researches have been conducted to investigate the best practices for energy efficiency in existing buildings. Among the technologies available in the market, the decision on which retrofit technology should be used for a specific project is a multi-objective optimization problem subject to many restrictions and limitations, such as special characteristics building, total available budget, project target, type of construction and services, efficiency, etc. The financial benefit is not the only criterion for the selection of retrofit technologies. The ideal solution is a trade-off between a number of energy, economic, technical, environmental, and social regulations (Ma, 2012).

1.2 BIM

BIM (Building Information Modeling) is an information model of the building, which treats the information of the building from design to operation, maintenance and demolition. Since BIM systems allow us to consider various dimensions of the project simultaneously,

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they introduce coordinated on the design process considerations of energy performance, of comfort, of construction processes and costs, and can offer guidance to designers in the choice of materials. They can be considered an evolution of CAD systems for managing information on the complete lifecycle of a construction project through a bank of information integrated to the modeling (Wong, 2015)

Green BIM can be considered the process based on a coordinated model of generation and management and consistent data of building during the project life cycle that increase the energy efficiency performance and facilitate compliance with established sustainability goals. It is the use of BIM tools to achieve sustainability and/or improvement in design performance. It is a tool that was created to assist in building design the efficient integration of sustainable components, especially implementation of energy efficiency in the building lifecycle project. Application of Green BIM should not limit the analysis at the design stage and construction, but the building life cycle, including phases of the operation, repair, maintenance and demolition (Wong, 2015).

1.3 BIM AND SUSTAINABLE RETROFIT

Existing buildings represent a large part of energy consumption, and because of great service life of these, you need to think of technological solutions to improve energy efficiency and indoor environmental quality. Among the many possibilities, it's necessary to identify the most appropriate options for retrofit is a major issue because of the potential costs and impacts involved, making decisions based on concrete evidence (Assadi, 2012). Although the implementations of BIM in new and existing buildings require profound changes in the processes involved, the benefits are considerable (Volk, 2014).

Outdated or non-existent projects and incomplete energy consumption data make it difficult to predict future performance over a renovation project. Unlike what happened in the 1970 energy crisis, nowadays technology allows to improve the performance of buildings and limit capital investment in projects that will generate the greatest economic and environmental return (Autodesk, 2010). The inefficient use of materials in terms of the embodied carbon mitigation is considered a key factor in the carbon footprint of the construction industry. Improvements in BIM tools help provide analysis of emissions mitigation options in terms of manufacturing materials, transportation and installation methods (Wong, 2015).

Among the main advantages of using the Green BIM for retrofit, include:

• Identify ways to reduce the consumption of natural resources.

• Increase on site renewable opportunities.

• Teamwork and consensus-building.

• Increase investor confidence with the view of the model.

• Meet the requirements for sustainable design and energy efficiency.

• Meet the requirements of environmental certifications.

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• Support an assessment of both the energy performance of construction projects and embodied energy in the materials and methods used in building construction.

• Reduce the carbon footprint by analyzing the embodied carbon and embodied energy in materials used.

• Exploitation and enhancement of luminous, thermal and acoustic analysis in projects.

• Minimizing the generation of waste.

• Parametric elements can be changed and updated throughout the project, performing simulations, which reduces conflicts between building elements, facilitates revisions and increases productivity.

• Database stores the attributes of the construction elements, allowing analysis in future projects, as well as comparisons in the use-phase of operation and maintenance of the building (facilities management).

According to Hammond (2011) and Autodesk (2010), some examples of design tools that can be used for sustainable retrofit using BIM are:

• Orientation - appropriate design guidance, allowing the site to be located by longitude and latitude, and optimize to solar passive strategies.

• Study of Volumetric -Allows good access to natural light, creating an immersive efficient building. BIM allows research with simple volumetric forms to compare settings.

• Envelope – Quality, resistance, permeability, and conductivity of materials, together with the isolation and the amount of glass are factors to be combined to determine the mass efficiency and building systems. BIM allows custom assemblies composition.

• Daylighting - Natural lighting reduces your need for artificial light in the space, thereby reducing the gain of internal heat and energy use. The BIM model can be used for daylighting simulations and shading options for indoor and outdoor conditions.

• Ventilation - Using prevailing breezes when possible for natural ventilation reduces the load on mechanical equipment.

• Energy: Using BIM analysis tools to help analyze heating and air conditioning requirements, identify daylight opportunities, and select the main building equipment can reduce energy use. Incorporate meteorological data and the local power grid to estimate building energy consumption and carbon emissions.

• Water: retrofit buildings to reduce the use of water or use alternative sources such as gray water and rainwater. Analyze options for providing potable water and not potable for the occupants and building processes. Evaluate rainwater systems, and simulate the performance of collection systems, ponds and culverts.

• Materials: Select recycled or renewable materials during building renovations. Consider the integrated projects that reduce rework and the resulting waste.

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2.CASE STUDIES

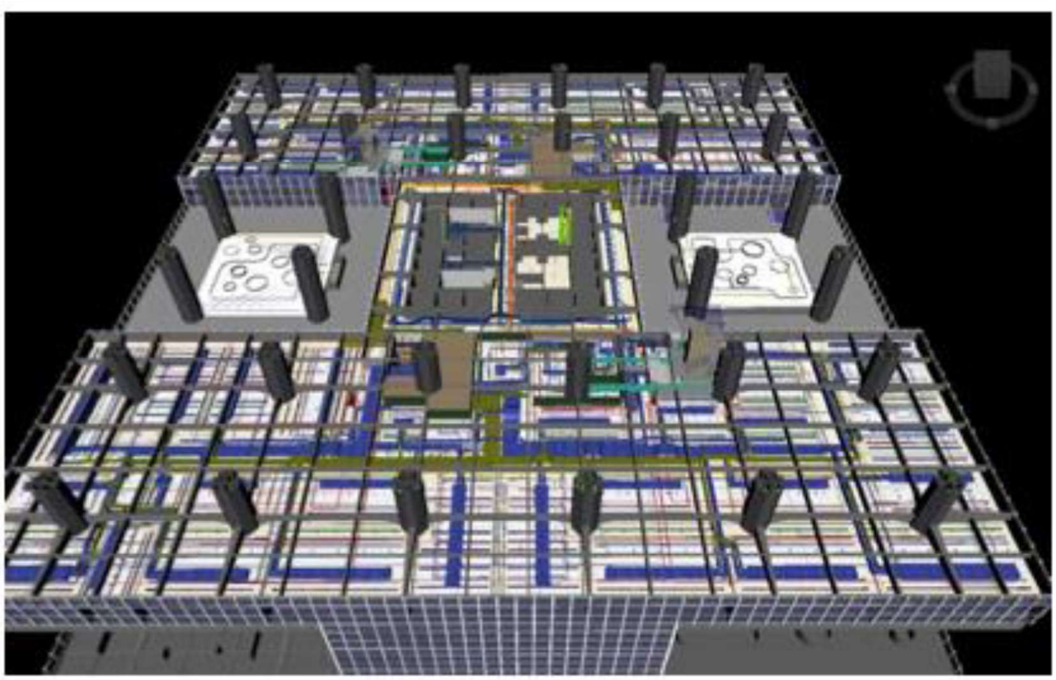
To illustrate the potential use of BIM for sustainable retrofit, will be demonstrated two case studies taken from the literature.

2.1 Commercial building

In the article " Plataforma BIM, retrofit e sustentabilidade ambiental: estudo de caso na cidade do Rio de Janeiro" "from Silva (2015) a case study of an enterprise is presented, whose project carried out in the 1960s had bioclimatic architecture principles: valuing the social life in pleasant surroundings and a desire to become a landmark in the city's architecture, especially in the landscape, but integrated with its surroundings.

Based on work previously performed on the 6th floor to increase energy savings, it developed a technology upgrade project aiming at adapting to current and future needs of the building. The study followed the modeling of the building, which began with the work provided and extended to the creation of the digital model of the entire set. With the modeling it was possible to create a database with all the information on the building to assist in maintenance management. Performance simulations still in the design phase and the ability to choose the best alternatives before the start of implementation, will allow the company to obtain environmental certification AQUA and energy labeling Procel Level A, which further justifies the production of the model in BIM. Among the features used in BIM are checking the interference, the use of management that allow the supervision and approval of documents by staff systems, the visualization of the 3D building model (Figure 1), the collaboration of a multidisciplinary team with exchange information to serve the AQUA certification requirements and the project management system in operational phase.

Figure 1 - Virtual Model of the building (Silva,2015)



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The main findings found in this research were:

• The adoption of BIM platform should preferably take place in the process and project start to use all the features that have occurred, which was not the case as the basic project of the previous works had been done in 2D.

• For the little familiarization of staff with BIM, the project development time was longer than usual.

• Because not all employees are familiar with the BIM platform it was to convert the retirement plans for AutoCad.

• Due to the advantages found as early solution of interference that could only be identified during the work, the company intends to use modeling in future projects.

• The project team defined a "block-pilot" to be modeled in BIM, allowing familiarizing professionals with new technology and enabled the identification of the technical bottlenecks in parts of the building where you realize the greatest amount of pipes and connections due to the crossing of different building systems.

• There was overlapping assignments of external coordinators, which was the lack of understanding of the participants to the possibilities offered by the use of the platform did not take full advantage of the technology, and repeated the schemes adopted in development projects in 2D.

• Creation of an enterprise database to facilitate operating activities and building maintenance as well as the realization of future reforms.

• The need for professionals who work in maintenance are qualified and familiar with the use of this tool in order to keep the database up to date.

• Establishment of a specific sector the company intended solely for research and development of technological solutions applied to construction, which will be devoted to the creation of a database that can add information to complement parametric modeling, making it an interesting strategy to be adopted in future projects.

2.2 EMOP Building

The study “O retrofit e a modelagem de informações como ferramenta de análise de projetos” from Guimarães (2014) presented the retrofit project for the 5th floor Construction Company headquarters of the State of Rio de Janeiro (EMOP) located in the Campo de São Cristóvão, in Rio de Janeiro. Besides the aim to adapt it technologically, replacing systems and changing the layout to adapt to current needs, the concern to reconcile the necessary changes and certain characteristics that refer to the original project, the project aims to encourage the retrofit in other floors.

The main construction resources used were internal panel-glass partitions coated with melamine laminate and core glass wool for transparency expected in the department; Facade tempered glass tinted with a thickness of 8 mm and solar control film, for the purpose of improving the thermal performance of the building and luminal;

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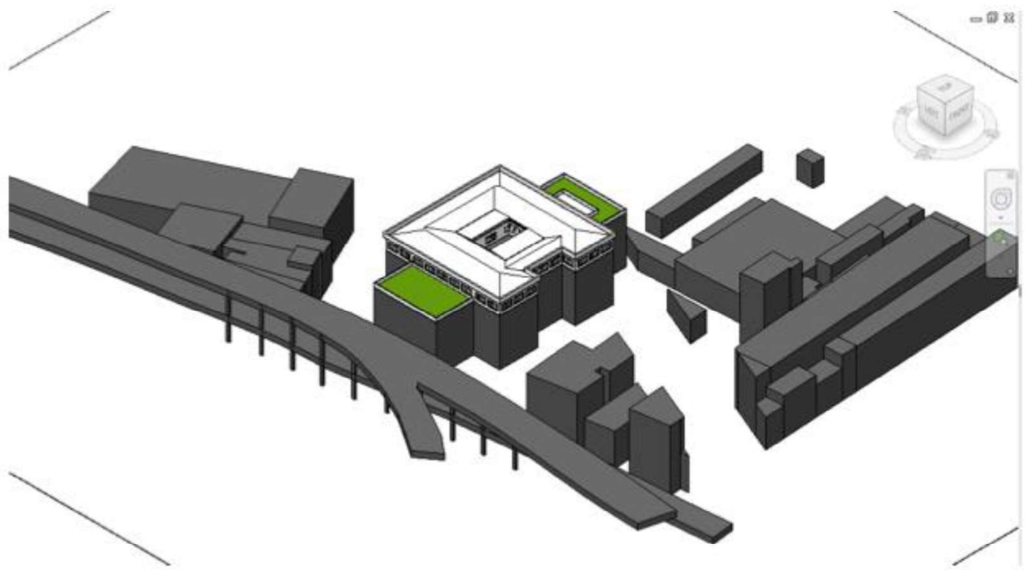
thermoacoustic lining in mineral fiber used in offices; in the honeycomb lining hallway was used to provide lightness to the environment and to facilitate the embedded systems, single air conditioner installed in the upper slab supplies cool air to the fancoletes. The latter did not work properly, which will be replaced in future project for central air conditioning duct.

Based on the retrofit project of the 5th floor of the EMOP developed 2D programs and information for the materials used in the work was prepared the 3D model in Revit, also considering the location, as shown in Figure 3, it is necessary latitude and longitude to suit the climate of the region and around the building in the performance analysis (Figure 4). It has also developed the volumes of the buildings of the surroundings and the red line due to the influence that these buildings have on the EMOP. Thus, it was possible to carry out performance reviews luminal, thermal energy (Figure 5) and acoustic in the building.

Figure 2- Surrounding volumetry (Guimarães,2014)



The main findings identified in this study were:

• The BIM has great potential, and with a consistent modeling, you can get close to reality results and evaluate changes that can improve the performance of the building.

• The project was initially developed in 2D, it has not been evaluated, using performance simulations during its design. The development of a model with information, as shown in this study, could have indicated the possibility of replacing materials for other similar with a better cost-benefit ratio.

• Many companies do not provide data for the material, making it difficult to obtain reliable results. The data consistency condition is one of the fundamental concepts for the use of BIM.

• We found difficulties in finding data that are complete and homogeneous of the same material.

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• Revit having embedded software analysis tool was used, but requires modeling with a higher degree of detail. If specific programs for analysis of building performance were used, this level of detail could be lower.

• economic analysis or detailed behavior of the materials or techniques used, which could be addressed in future studies were not considered.

• It is also suggested as a possible future study the integration of environmental certifications to BIM projects.

3.CONCLUSIONS

The BIM model allows quantifying, planning, coordinating and retrieving information over the building life cycle. In this study it was revealed that the inherent nature of BIM integration makes it an ideal tool for application of sustainable design principles, as this facilitates collaboration between professionals from different areas in the early stages of construction, allowing discussions to start them. Among the main advantages of BIM for sustainable retrofit include: increasing energy efficiency, reducing water consumption and waste generation, the analysis of project interference, project alternatives of testing possibilities and tests on the model behavior.

By analyzing the case studies, it was possible to see that as Green BIM has been little used, the process is still immature and not systematized. In both case studies, projects were initiated in 2D, only moving to BIM platform at later stages, which affect the use of the tools available and the design choices. Both Silva (2015) and Guimarães (2014) point out that the main limitation found was the lack of staff training and little staff familiarization with the system functionality, resulting in loss of time in the design process.

Another limitation mentioned by Guimarães (2014) was the difficulty of obtaining reliable data, complete and homogeneous regarding the materials, which can be solved with the PBACV (Brazilian Program of Life Cycle Analysis) that is creating a Brazilian database.

For Silva (2015) the creation of a building's database will enable better understanding of the building as well as its use in future projects and maintenance.

Regarding the environmental certifications, Silva (2015) sought to AQUA and PROCEL level A, while Guimarães (2014) suggests as future study the possibility to integrate environmental certifications to BIM projects.

Due to the great potential of BIM and the advantages found in its use, Guimarães (2014) and Silva (2015) recommend their use in future studies.

It is noteworthy that the buildings analyzed have different magnitudes. So while Guimarães (2014) studies an office building floor of EMOP, Silva (2015) considers the 26 building floors Petrobras main office. Based on these data, a comparative analysis of two case studies is limited because the project needs, work teams and the amount of information obtained are different.

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As future research possibilities are the practical application and improvement of tools for its realization, seeking to identify the most appropriate options according to the potential costs, reduce environmental impacts involved and the possibility of environmental certification.

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