Building Information Modelling (BIM)-Supported Cooperative Design in Sustainable Renovation Projects

Benefits and Limitations

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Abstract. This paper presents and demonstrates the main benefits and limitations of the BIM technology in sustainable renovation projects. The built environment is acknowledged as a value both as material and cultural resource to be preserved. The set of buildings that constitutes the built environment represents a valuable deposit of meanings and knowledge. A proper conservation of the built environment is expressed by a sustainable use of materials and territories/lands that have to be preserved for the future generations. Furthermore, undertaking a sustainable way to renovate the buildings means to improve the quality of life and health of people/inhabitants. There are many differences between the design of new buildings from scratch and the renovation of existing buildings. In the latter case, the designer has to tackle the difficulties that arise from the real buildings, represented by a set of constraints (i.e.: walls, beams, spaces, etc.). Digital tools, and in particular Building Information Modeling (BIM), make manageable and improve the design, organization and construction of renovation projects. The benefits using BIM during cooperative design for sustainable renovation projects affect the three dimensions of sustainability (environmental, economical and social) but there are also limitations that delay its diffusion in this field within the AEC sector.

Keywords: BIM, sustainability, renovation, digital reconstruction, integrated design.

1 Introduction

This paper presents and demonstrates the main benefits and limitations of the BIM technology in sustainable renovation projects. The built environment is acknowledged as a value both as material and cultural resource to be preserved. The set of buildings that constitutes the built environment represents a valuable deposit of meanings and knowledge, considered also as used constructive techniques, energy and materials. A proper conservation of the built environment is expressed (beyond the cultural reasons) by a sustainable use of materials and territories/lands (it reduces the con-

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sumption) that have to be preserved for the future generations. Furthermore, undertaking a sustainable way to renovate the buildings means to improve the quality of life and health of people/inhabitants. Last, but not the least, in this time of global crisis, the renovation of existing buildings is also worth on the economic point of view. There are many differences between the design of new buildings from scratch and the renovation of existing buildings. In the latter case, the designer has to tackle the difficulties that arise from the real buildings, represented by a set of constraints (i.e.: walls, beams, spaces, etc.). We believe that digital tools, and in particular Building Information Modeling (BIM), make manageable and improve the design, organization and construction of renovation project.

2 Sustainable Renovation Projects

2.1 Renovation and Sustainability

With the expression to renovate, we do not want to simply specify the restoration of an existing condition, namely the original performances, but we want to improve it for the same use or for a new destination. During a renovation project, the designer has to find spatial and technical solutions to satisfy the user's needs using a creative way against the constraints that come from existing buildings. Current environmental issues require that any action will be also sustainable, namely all the choices carried out during the various phases of the life cycle of the building have to minimize and optimize the material consumption and the waste production. In synthesis, the renovation project can be defined sustainable when it minimizes the negative impact of the building on the built environment.
Among the actions to undertake during a renovation project there are the following:

- to take into account the natural and artificial characteristics of the site/context and the building orientation during the design phase;
- to prefer the use of renewable, recycled and recyclable materials;
- to choose dried connection systems, easy to assemble/disassemble/substitute;
- to integrate devices for energy saving: photovoltaic and/or wind system, etc.

In this paper, we decided to focus only on residential buildings with a concrete bearing structure inside.

2.2 Residential Buildings with a Concrete Bearing Structure

Among the residential buildings in reinforced concrete, we have paid attention to those who mainly use a structural grid defined by technical vertical linear elements (columns) with squared or rectangular section (rarely polygonal) and horizontal elements (beams and plates) that form a structural frame. Such a system usually presents one or more basic modules (i.e. the distance between two columns) repeated inside the building, in plan and elevation. In many places around the world in buildings with frame in reinforced concrete, the closings, that divide the inner and outer spaces, and the internal partitions are made with bricks, such as hollow brick or common brick.

During a renovation project the technological units of the building system that have to be analyzed, including the structure in reinforced concrete, could be synthesized using a classification scheme suggested by the Italian UNI Norms: s*tructures, closures, internal partitions, external partitions and plant delivery services* [1].
Is it possible to extend the life of these buildings, by preserving their main reinforced concrete structure and with the improvement of the functional, energy and aesthetic aspects?

2.3 Main Issue: Managing the Complexity

The high number of elements that constitute a building, its correlations, functional diversity, performance requirements and set of used materials make the analysis of an artifact a complex problem. All these aspects are more and more difficult to be managed with only traditional tools and methods; furthermore the best way to manage all these information as a potential solution is to apply an integrated approach - Building Information Modelling. The largest and worst limitation of the conventional aspect to the renovation project is the inadequate and ineffective collaboration and communication between the various stakeholders of the process. The contribution to the project are disconnected and this way of proceeding increases the risk of mistakes.

3 Cooperative Design

To manage all the variables/issues present in a sustainable renovation project in a proper way, also if we are working with residential buildings of small/medium size, it is necessary to collaborate with other professionals, each one experts of a particular subject: structures, materials, energy, etc. It is essential such a collaboration to achieve a common objective in an effective manner. In this context we prefer to refer to the word "cooperative", that in the Oxford Dictionaries online it is an adjective that means "involving mutual assistance in working towards a common goal" [2]. We prefer to use this word instead of "collaborative" because, according to Kvan [3] "*collaboration is a deeper, more personal synergistic process [...]. Perhaps we should refer to our field as "co-operative" design process itself is one of negotiation, agreement, compromise, satisfying in order to achieve success*".

The use of digital technologies inside architectural practices has contributed to considerably reduce the number of mistakes. New methods and tools such as CAD and 3d modeling software packages, spreadsheets, etc. have allowed to improve efficiency and productivity compared to traditional methods and tools [4]. A cooperative approach during the design phase of sustainable renovation projects imply a tight collaboration between all the stakeholders.

Furthermore, according with Rifkin [5], we believe that digital technologies, and in particular internet, together with renewable energies will change our society starting with the traditional hierarchy of the economical and political power. We will witness a new organizational system characterized by interconnected nodes, similarly to the one of the world wide web.

4 BIM: A General Introduction

The term BIM not only introduces new tools, but mainly new concepts and processes. The introduction of BIM in the AEC sector (Architecture, Engineering, Construction) is needed for several reasons, including the improvement of cross-disciplinary communication, collaboration and the production and management of the information of an artifact. Over the years, after following an evolutionary path, the two-dimensional objects, elaborated with the first CAD software, acquired the third dimension (with the introduction of 3D modeling), and they have been enriched (through BIM) in properties, data and information of various kind (that could be referred to any phase of the life cycle of the artifact). *"Traditional architectural drawings and CAD models abstract away from the supply chain, but Building Information Modeling databases make it explicit, designable, and manageable"* [6]. BIM technology is widely diffused in the design, construction and management of new buildings but barely in interventions focused on existing buildings. The use of the BIM in the documentation, analysis and renovation of the built environment is not very diffused yet, although there are examples in this regard [7] and [8]. In this latter publication there is an interesting case study about the transformation of the Toronto National Building in a Contemporary Hotel that use BIM (Autodesk Revit) in Remodeling and for LEED Certification. However, it is possible to assist to a gradual increase of interest among researchers and expertise in the application of BIM in this sector. This new trend was understood by the big software houses that started including in the new versions of their software functions that allow to import in the BIM environment also the point cloud [9].

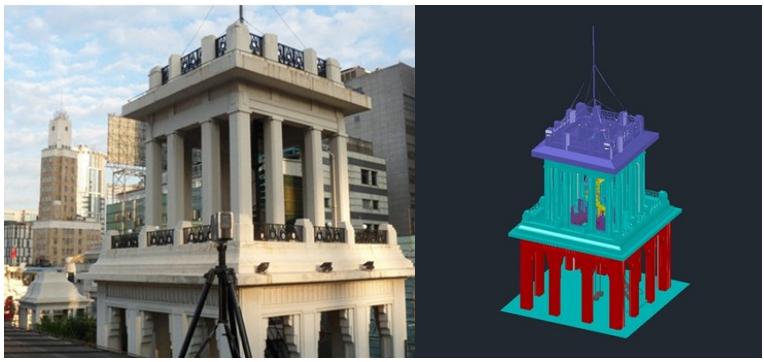
Beside the parametric objects, one of the most important features of BIM is to incentivize, support and improve the collaboration and communication between all the project team members, this means a reduction of the risk factors that create waste of resources.

5 Case Study

This section presents a case study of the application BIM technology in existing building renovation,

This BIM is based on a three-dimensional digital technology-based which integrated data model of information engineering construction projects. BIM is detailed expression of this project and an approach which supports the integrated management of the environment of the construction works, digitization methods in the design, construction, management. Construction work can significantly improve the efficiency and significantly reduce the risk of its entire process (see Figure below). There are also five major characteristics:

1. Visualization --- what you see is what you get;
2. Coordination --- professional collaborative design;
3. Analog --- energy-efficient analog, emergency evacuation simulation to simulate sunshine, heat conduction simulation, 4D, 5D;
4. Optimization --- design, construction and operational phase;
5. Easy for drawing --- architectural diagram, component diagram, integrated pipeline map, comprehensive structural drawing for left holes.



(a) (b)

Fig. 1. On-site scanning for BIM scene reconstruction; (b) BIM 3D model

Fig. 2. Point clouds data

6 BIM and Sustainable Renovation Projects: Benefits

The benefits using BIM during cooperative design for sustainable renovation projects affect the three dimensions of sustainability, namely: environmental, economical and social. We decided to classify these benefits in two main categories concerning the collaborative and the technical/constructive aspects. The main categories present also subcategories. We will highlight the main benefits dividing them in two main categories, but we are aware that sometimes there are intersections and overlaps between them.

- Benefits concerning the collaborative aspects:
  - collaborative aspects within the design team:
    - *Integrated design:* the use of a central Building Information Model improves the collaboration of the stakeholders (architects, engineers, constructors, etc.) and reduce the chance of mistakes; this model represents the central element of the communication between all the stakeholders;

  - collaborative aspects within the AEC sector:
    - the use of BIM processes and technologies could contribute in the creation of a network of relationships between the local producers of technical elements and materials, improving the collaboration and communication. The local producers could prepare a database with all their technical components (with dimensional, material, etc. characteristics) in BIM format, ready to be used and evaluate inside the digital model. For example we thought to technical elements built using materials according to the local context: wood essences, cork, coconut fiber, sheep wool, raw earth, straw bale, etc.
  - within both situations the use of a shared model contributes to reduce the so called "island of automation".
- Benefits concerning the technical/constructive aspects (these aspects influence positively also the economical side):
  - *parametric design*: to adapt the same technical solution to different parts of the building changing few parameters; this will reduce the costs and the production of construction wastes;
  - *clash detection*: all the design solutions proposed by the stakeholders can be integrated and visually evaluated in the same 3d model, in this way it is possible to identify possible conflicts with the existing structure and/or with the design proposals elaborated by other specialists (i.e. structural and mechanical components);
  - the opportunity to simulate and hence study and evaluate also the constructability and the site management (evaluate the deployment of the technical elements and facilities inside the construction site);
  - a better definition of the project from the initial stages and the opportunity to investigate and evaluate various design alternatives using the same digital model permits to optimize and hence reduce the costs of the construction labor and the production of waste;
  - the chance to link the information and to make them interdependent, namely a parameter modified in the BIM will automatically occur in the other schedules/files and vice versa.

7 BIM and Sustainable Renovation Projects: Limitations

The limitations of the use of BIM in sustainable renovation projects rely on different factors that could be lead back to issues within the AEC sector and :

- Limitations connected to the existing building to renovate:
  - the lacking of quantity and quality in the documentation related to the most part the existing residential buildings;
  - to produce a proper documentation of the existing structure in a digital environment through a laser scanner followed by the creation of the surface model (in this regards please see again the); hence in that case, the dimensional and morphological accuracy of the 3d model in the BIM environment relies on this preliminary step.

- Limitations connected to the AEC sector:
  - the technological backwardness that characterizes the construction industry compared to other fields such as automotive and aerospace. The AEC sector is often hangs on to concepts, methods, processes and tools that didn't changed too much during the years [10].
- Limitations connected to the BIM:
  - the learning curve that characterizes a BIM could represent a difficulty for people that are accustomed to use the same CAD software for years;
  - the architectural practices and the other specialists should afford the training costs of their employees (architects, engineers, etc.), generally not all the practices agree to spend money in this way, even if it is an investment for their future;
  - not all the tools and processes inside the BIM environment are adequately streamlined; the software package should supports the design process making it easier (also for what concern the 3D modeling aspects), the main objective must be to produce a good project and to manage in a proper way all the information through the whole life cycle;
  - the specific ontology (classification of elements) used by a BIM could be a limitation compared to the wide number of technical elements that we can find in a real building;
  - *interoperability*: even if a lot of effort has been done on the interoperability side (i.e. with IFC), there is still a lot of work to improve the communication between the different software packages.

8 Final Remarks and Conclusions

In this paper we presented the main benefits and limitations of BIM as supportive tool and method in the cooperative design for sustainable renovation projects.

The BIM technology represents the ideal cooperative and communicative platform to promote and put in practice a cooperative approach to the renovation/reuse project of residential building pertaining to the built environment. The same technology could foster the definition of a network of relationships between the local producers of technical elements and materials.

With BIM it is possible to gain a better control of the project and so to minimize the use of resources and the production of waste along the whole lifecycle process.

Principles of sustainability together with BIM will re-shape the design process and the architectural/engineering practices throughout a redefinition/update of the roles. According with Cohen [11] we believe that it is necessary a new professional figure, a "project information architect" able to, as a movie director, coordinate and manage a new flexible, networked organization of professionals and businesses.

The reflections and concepts elaborated and presented in this paper could also be applied both to residential buildings that use a structural grid with columns and beams made by other materials (i.e. wood, steel, etc.) and to non residential buildings pertaining to any cultural context.

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