Aesthetics and Visualization of Building Projects in BIM Environment

Estetica și vizualizarea proiectelor de construcții în mediul BIM

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Abstract. *In this paper we aim to analyse a current issue such as "Building Information Modelling" or modelling information in construction from a project manager's point of view. BIM is a digital tool for creating and using coordinated information in a single construction project. Generally, this model is defined as a 3D model from which the information required for each design or execution phase is extracted. 4D dimension refers to time-related information, 5D to cost information, 6D to sustainability, 7D to facility management, 8D to safety during design and building, 9D to "Lean" building concept and 10D to construction industrialization. The authors suggest the transformation of BIM 9D from Building Lean into BIM 9D project "aesthetics and visualization".*

Keywords: BIM, 9D BIM, rendering, project management, building industrialization, aesthetics, visualization.

1. Introduction

Building information Modelling (BIM) is a virtual model-based work environment that simulates the physical and functional aspects of a building and contains information about the characteristics of each building component. BIM is a collaborative process because the model is built by various stakeholders in the design and building phases (architects or designers, engineers, economists, constructors), encompassing as an information exchange resource and a reliable source for making decisions about a building, throughout its life cycle, see [1].

However, there are various computer applications called "BIM" that allow different actors to create, interact, extract information or manage the building from a virtual model. Some examples are ArchiCAD and Revit for architectural and

engineering design, Tekla for structural details, Vico for budgeting and building management, Solibri for the Virtual Model's analysis and consultation and ArchiFM for facility management, see [1]. Furthermore, there are many others in the market.

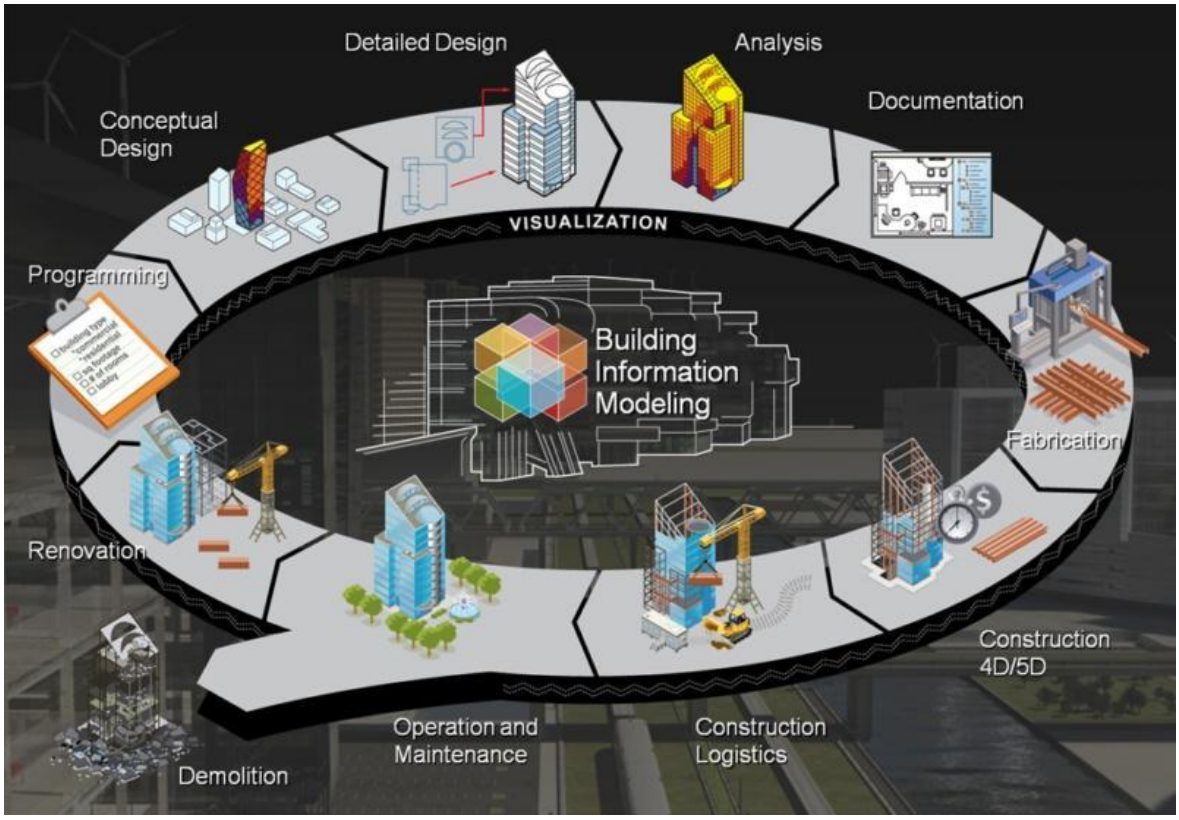

Fig. 1. Implementation of the BIM concept (source: Connectabim,www.connectabim.com/about-bim/)

It is paramount how manufacturers can participate in the development of BIM platforms. BIM methodology assumes that the virtual model is as close to reality as possible. As is the case in industry, the role of producers is essential, as only with their products the construction can be executed. The BIM model also requires the use of materials and equipment in digital format. Manufacturers should provide digital versions of their products in BIM content format or be prepared to intervene in developing the virtual model within the BIM collaboration process.

In the absence of products in BIM format, designers tend to use generic products in their projects to which they associate only minimal information. More information will subsequently be added with the product information that is currently in use. Product availability in BIM format allows specification selection and detailing in the early stages of design. There is a higher probability of product on site effective application when it is inserted and specified in a BIM model.

CAD is a technology that was born in the early '80s. Later, in the '90s, it was used globally as a tool to support project design. Although it is still used for design

support since the beginning of the century, CAD has been replaced by powerful BIM tools that manage all information about the project, including the design.

As for libraries, in addition to improving geometry, BIM objects contain among others product information data on branding, reference, finish available. They are often interactive and allow users to select different options and better understand the product operation. CAD libraries contain only product geometry, usually with too much details and in files that are not suitable for design use.Also, CAD files often support BIM libraries production, which is another manner to monetize a previous investment.

A notable example illustrating this cycle is the United Kingdom. In 2012, a law was imposed and, in 2016, the whole industry should have been linked to design, construction and adaptation in order to use BIM methodologies for public works.

In the US, BIM has been a requirement of the Department of Defence for many years.In the Nordic countries, BIM is not only the most common working methodology, but also most of these countries already have national BIM standards.

Also, in eastern countries like China, Japan, and Singapore, BIM is a technology that has been around for a long time. In the past few years, global construction has become more and more complex. BIM is the technology that supports this new capability, andmanufacturers of building products should be a part of it.

Building Information Modelling (BIM) enhances the way projects are carried out and managed worldwide. It provides a revolutionary platform for the conception, construction, maintenance and operation of our built environment. In addition, BIM also changes the way we make improvements (rehabilitation, modernization and redevelopment) to existing assets in the built environment, see [8].

We have now reached an interesting stage in the evolution of BIM, where a significant number of stakeholders in the construction sector are either using BIM or considering using it. This development is particularly relevant in mature markets, although the level of adoption of BIM varies by country, the size and complexity of projects, and the size and nature of each specific organization. The managers of BIM are recognized in this context and are a very important element in the approach of a construction project.

This paper aims to address this balance by emphasizing the relevance of BIM to project management as a discipline and vice versa, the importance of integrated project management in BIM for the effective execution of projects in the built environment. It describes BIM based on a project leader's vision of the world by defining project management processes that operate in a BIM-compatible environment and by highlighting future trends in project management practice that could result from the adoption of emerging technologies in the built environment sector, see [9] and [11].

2. Description of the roots of the topic approached

2.1. BIM Dimensions

The concept of BIM is still quite new in the construction industry in Romania and therefore the implementation requires large investments in education and technology. BIM is evolving very quickly and we are glad to see that its standards are also translated into Romanian. In the course of this paper, in 2023, 7 BIM dimensions were recognised. One can extract 2D BIM, that is, one can say that BIM begins in 3D, and 2D BIM does not exist. 2D is a flat dimension, in particular plans and 2D sections. CAD computer-aided design began in the 1960s, and the concept of BIM appeared in 1957, and the first software developed for the public by Graphisoft in 1987-ARchiCad, was introduced in 1970. It is the first software to make 2D drawings and 3D geometry. Officially, according to Biblus, Autodesk, see [2], United-BIM are recognized as 7 BIM (7D) sizes, but they can go even further because it is an ever-changing concept, see [7]. In addition to the aforementioned 7 dimensions, there is now an open debate about three "new dimensions of BIM".

Fig. 2. BIM from 3D to 10D (source: Biblus, https://biblus.accasoftware.com/en/wp-content/uploads/sites/2/2018/04/dimensions-of-BIM-2.jpg)

Below we list the BIM dimensions from 3D to 10D that we will detail in the following chapters, see [3] and [4]:

- 3D - 3D modelling, graphic information;
- 4D - 4D information, time-related, construction sequencing by Gantt charts and timeline;

- 5D - 5D cost analysis, cost management, construction cost estimation etc.;
- 6D-Sustainability 6D, Environmental, Economic and Social Sustainability Impact Studies;
- 7D - Life cycle and maintenance 7D, Facility Management: planning and managing maintenance operations throughout the building life cycle;
- 8D - safety during design and construction;
- 9D - Construction optimization in the implementation phase is the 9thdimension of BIM;
- 10D -The 10th dimension of BIM refers to the industrialization of construction.

In the following, we will focus on describing dimensions 8D, 9D and 10D and the proposal to improve dimension 9D.

2.2. Description of BIM 8D - Safety during design and execution

Safety during execution can be anticipated from the design phase. This is very important, because 8D BIM is the dimension of BIM that supports you in managing safety on construction sites and it helps you prevent risks and hazards to workers from the design period.

8D BIM is the BIM dimension that adds safety information to the geometric design of the construction during the design and execution phases. In practice, it is possible to model the site with all its elements (fencing, storage spaces, scaffolding, machinery, indicators, etc.) and visualize it realistically, thanks to advanced technologies such as virtual reality and augmented reality. It is possible to accurately render the site through virtual reality glasses. To achieve these results, one needs specific software that is equipped with special libraries with dedicated objects and simulates any type of machine and construction equipment so that one can produce the most suitable models.

The aim is to have an overview of the site already in the design phase to prevent possible risks and hazards for workers. Viewing the site in advance and in a realistic manner allows an easier and more efficient analysis of all possible scenarios and prevents hazards and critical situations at every stage of the project.

The main advantages of site safety management are:

- having a full picture of the possible scenarios to work on the site;
- drawing up detailed safety plans to date;
- accurately identify and analyse the most appropriate choices for execution safety;

- preventing risks by interfering with design choices that may generate potential hazards;
- viewing the digital site in 3D;
- training workers through virtual reality;
- reducing the risk of accidents.

2.3. Description of BIM 9D - “Lean” construction

9D BIM, also known as lean construction, is the BIM size that optimizes and streamlines all steps involved in implementing a project by digitizing processes.

Lack of planning on a site can lead to delays in project delivery and, consequently, to an increase in the initial budget. 9D BIM is the method designed to completely eliminate losses, optimize all resources involved in the construction process and increase productivity.

Undoubtedly, all these aspects contribute to the achievement of a valuable final product.

The principles on which the lean construction is based are:

- optimize, reduce or eliminate activities that do not add value to the process-In order to achieve process improvement, particular attention is paid to all aspects of the supply chain (from production, to the transport of materials to the site). The entire production chain is analysed, unnecessary or repetitive processes are identified and strategies are developed to simplify or replace them. For example, the use of means of transport is planned to be optimized and perfectly adapted to the quantities to be transported.With this in mind, it is preferable to use larger trucks for transporting materials, reducing the number of transports required;
- taking into account the needs of the customer -Before starting any project, it is necessary to identify the needs of the client through market research and satisfaction surveys, even in the case of projects that have already been delivered. Activities that do not add value to the process are not of interest to the customer and therefore he is not willing to pay for them. On the other hand, focusing on customer needs is more likely to make all operations work smoothly;
- process standardization - Construction is one of the sectors with the highest rate of unforeseen events: each project is unique and unique are also the conditions that come into play on the site (completion time, workmanship, local conditions, availability of equipment and materials, etc.). In order to minimize site diversification, standardized construction processes should be adopted,

reducing the possibility of problems and improving the ability to manage unforeseen events. Reducing these variables allows the construction company to maintain a predefined standard and ensure a smoother and safer process;

- time optimisation -The time variable is influenced by transport activities, waiting, processing, inspection, etc. The optimization of all these activities has an impact on the quality of the work and the delivery times of the customers;
- Increased transparency -This principle contributes to a greater participation of all those involved in the process, who can actively and more consciously intervene in the development of solutions for improvement.

The way in which the construction process is managed differs between traditional and lean construction methods. In the lean method, the activities are divided into:

- activities that add value to the project;
- activities that do not add value to the project.

The concept of value is directly related to the degree of customer satisfaction, therefore, if the customer is not willing to pay for a particular activity, it is categorized as an activity that does not add value to the final product. According to this criterion, lean thinking aims to eliminate as many losses as possible already from the project management phase. In the traditional method, however, the activities are divided into sub-processes, and the criterion is not the degree of customer satisfaction. There is no careful management of losses and no planning of activities in the preliminary phase.

2.4. Description of BIM 10D - construction industrialization

10D BIM aims to industrialize and make the construction sector more productive thanks to the integration of new technologies and real-time information. It is possible to achieve 10D BIM by using tools for the digitization of civil constructions such as the BIM management system, which makes it possible to align all those involved in the construction life cycle and optimize each stage. The advantages of 10D BIM for the project manager are:

- reducing the construction time of the building envelopes;
- optimization of site costs;
- improving and implementing work safety measures;
- increased construction quality thanks to state-of-the-art digital infrastructure;
- precise control at each stage of production of each individual element through advanced, codified and standardized processes;
- no dependence on weather conditions that may affect the activities of the site.

All dimensions of BIM have as common objective the 10thdimension, which aims to develop the construction sector and increase productivity, thanks to new technologies and process digitalization. 10D BIM is the key to solving the problem of low productivity in the construction industry and to optimize every phase of the building life cycle: The design, construction and management of infrastructure or equipment. In this regard, 10D BIM works as a tool that centralizes data to optimize all project activities based on the use of technology. This means that project managers will have the resources to carry out the project in the best possible way. 10D BIM has the promise to provide a complete vision for asset management (during the design, construction and maintenance phases). It can therefore be used to align the financial, commercial, environmental, health and safety, risk analysis, etc. sectors. In this context, the 10D BIM tool offers countless possibilities for all types of projects and it can be used at all stages with the support of highly intelligent digital technologies and resources that automate even the most complex tasks.

3.Case Study

In the following we will present a case study of a modern housing with the following characteristics:

- Height regime - semi-basement and ground floor,
- House location - Bistrița, Bistrița-Năsăud county,
- Designer - **Construct**,
- Beneficiary - private investment,
- Budget for the investment - 200.000 $,
- Location - difficult terrain on slope.

The idea of the project started from the integration of floating volumes giving the sensation of levitation. The composition consists of three volumes: a single prismatic volume at the semi-basement level that is very well integrated in the slope of the ground, a second volume which represents the exit in the cantilever principle, giving a feeling of levitation, and the third volume is the living room as vertical dominance of composition. Through this study we will analyse the information of the building model and how time and cost control are affected throughout the project. Following the theoretical documentation, we will analyse the project on the following levels, see [10]:

- 2D documentation - plans and sections extracted from the 3D model
- 3D BIM -Geometry, analysis of the 3D model
- 4D BIM -time, planning and duration of implementation
- 5D BIM -cost estimate and budget

- 6D BIM 6D -sustainability, energy efficiency

3.1. 2D Documentation

The transition from 2D CAD to 3D allows architects, civil engineers and designers to work more efficiently and accurately. However, given that 2D drawings still dominate the project's deliverables, the ability to work in both 2D and 3D is beneficial. It is very important to extract the 2D drawings from the 3D models because in our country most public institutions require printed documents filed. The final electronic format as documentation is also represented by 2D drawings in pdf format and in some cases DWG. As technology advances very quickly, it is possible that in the future the final deliverable will be a single digital 3D model.

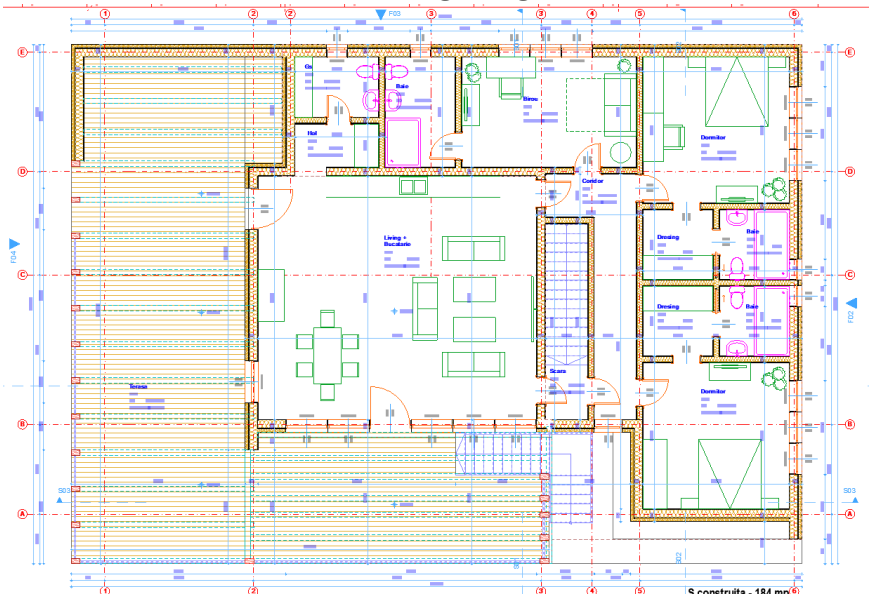

Fig. 3. Execution plan (source: Personal portfolio)

Functionally, the ground floor consists of a living room with kitchen, bathroom, 2 bedrooms with bathroom and dressing, office with private bathroom, circulation and access ladder from the basement, covered terrace. The infrastructure is a mixed one made of concrete diaphragms and reinforced concrete frames. The superstructure is made of load-bearing walls of „framing" type. The covering is a terrace with an inclination of 3% in the north-south direction.

The 2D documentation is extracted from the 3D model.Three-dimensional walls were used to make the 3D model, and the plan shows their 2D projection. Stairs, windows, doors, furniture are made of 3D objects. In the plan we see their representation on the 2 dimensions.

3.2. 3D BIM

3D BIM, as it is well known, represents the three geographical dimensions (*x*,*y*,*z*) of a building's structure. Geographic capabilities help stakeholders to visualize the structure of a building in 3 dimensions just before the project starts. The BIM 3D environment allows all stakeholders to collaborate effectively in shaping and solving typical structural problems. Also, because everything is stored in a central location, which is the BIM model, it becomes easier to solve problems in the next stage. When it comes to 3D BIM, it involves creating a 3D model and sharing the same information using a common data environment (CDE).

The benefits of 3D BIM are:

- Improved 3D view of the entire project,
- Simplified communication and sharing of design expectations,
- Easy collaboration between multiple teams, regardless of their field of expertise,
- Reducing the number of changes and revisions due to total transparency from the start.

Fig. 4. Volume extracted from 3D model (source: Personal portfolio)

We present the realization of the 3D model of the individual dwelling made on a slope plot. Due to the gradient of the terrain, making the 3D model becomes more difficult to achieve. For the 3D model we used three-dimensional elements such as walls and floor coverings for exterior closures. For the construction of the structure we used poles and beams but also composite elements on the area where the structure is made of wood. GDL objects were used for windows, doors, stairs, see [5]. GDL is the abbreviation „Geometric Description Language”, a functional programming language based on „BASIC”. It was created to encourage architects to use this language to build their own geometrical objects through the possibilities of design and presentation.

In 3D field modelling, a collaboration between the topographic engineer, architects and engineers takes place. This is how the topographic engineer performs the topographic lifting in stereo coordinates 70. From these coordinates can be made a 3D model of the land.

The advantages of 3D modelling are among others:

- you can study different possibilities of housing on the ground;
- accurate measurements of the level quotas. These measurements are made against the 0.00 elevation of the construction and are very accurate to the gradient of the land.
- precise technique of „cut and fill”- cutting and filling. More precisely, we can figure out where to cut the soil and what volume we get for a better systematization of the land.

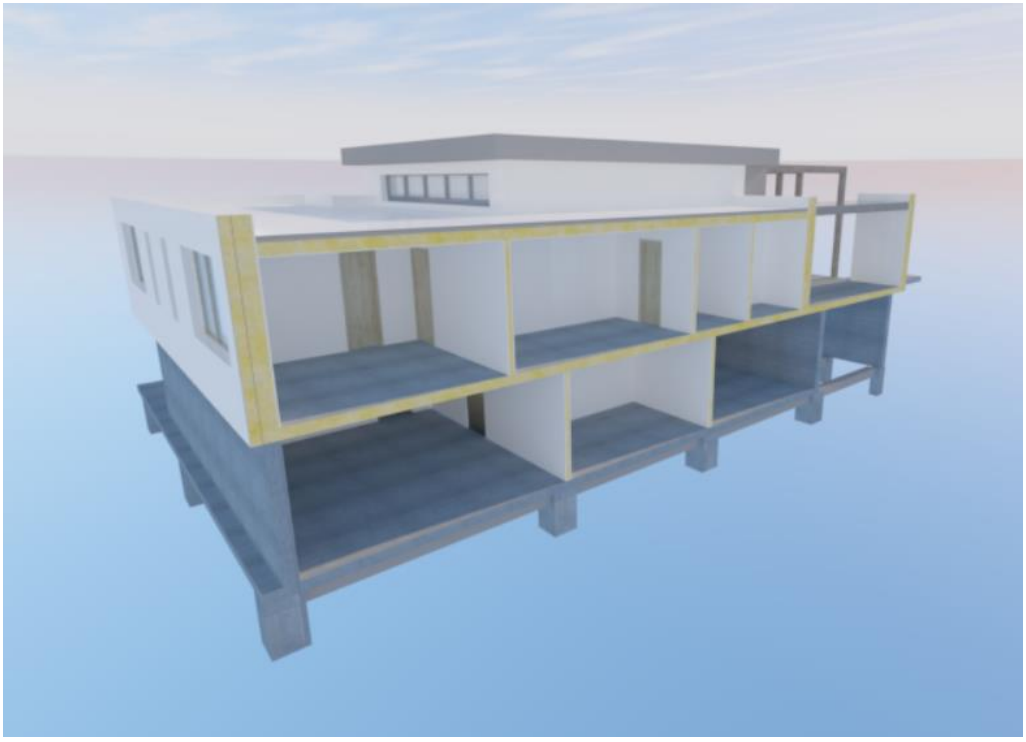

Fig. 5. Three-dimensional section through 3D model (source: Personal portfolio)

3.2. A Graphic Shortcoming of Playing in BIM

As can be seen, a shortcoming of representations in the BIM environment is that they do not address in an aesthetically friendly way the final beneficiary of the construction.

Fig. 6. Render final Model (source: Personal portfolio)

The image above is a rendering extracted from the 3D model and passed through various software to render the reality as best as possible. In general, these architectural renderings are made by architects and designers to give customers a picture as close to reality as possible with the future construction before it is executed.

We believe that a project manager must present his idea to the client in a very convincing way. Whether you present this idea in a traditional way through plans, compared to sections, you need to convince the potential customer by offering the most optimal and attractive solutions. On the architectural visualizations that we have not talked about, we would like to point out that in all construction projects it is very important aesthetics. A successful project must convince both the beneficiaries and the society that it is well integrated in the environment.

Fig. 7. Rendering of interior living (source: Personal portfolio)

In addition to the technique used by each project manager and solving the function of each construction, we also need to take care of the aesthetic side of things in order to become more convincing toward customers and friendlier to the built environment. With new technologies we advanced from 3D rendered images to the next level. Realistic photo videos play an important role in the industry and detail information for a better understanding of the project. A video shows the construction from multiple angles of view to better understand it. The construction is rendered by the materials used by light and shade, resulting in something very close to the expected final result.

Renderings are the most widespread representation techniques globally, but the latest presentation technologies are virtual reality ones. When it comes to interior design, the best way to visualize a space is through augmented reality. Through VR we can communicate the value of the project, what the specifications and features are and motivate the planning and construction costs in a much more interactive way. With VR we can use an infinity of furniture pieces and arrange them in the room to achieve the desired result.

Fig. 8. Render living from different angle (source: Personal portfolio)

All three ways of presenting a project are extracted from the 3D BIM model. The more detailed the model, the more spectacular the presentations will be. We wanted to recall the three presentation modes, traditional rendering, video presentations and virtual reality and emphasize the need to be introduced into one of the 10 dimensions of BIM or even reach the 11th dimension of BIM.

At the beginning of this section we talked about the graphic representation of elements in constructions and along the way, the idea of integrating the presentation of a project on the aesthetic leitmotiv was formed in one of the 10 dimensions of BIM.

Analysing the 10 BIM dimensions presented at the beginning: 3D BIM that refers to shape and geometry, 4D BIM that refers to time, 5D BIM that refers to costs, 6D BIM that refers to sustainability and 7D BIM that refers to facility management in buildings, they prove to be very well defined by the community and users.

It remains to be debated whether the other three dimensions of BIM are relevant. If we start with 8D safety during design and execution this is very important from our point of view and we have to keep it in mind from the design phase to the construction exploitation phase.

9D BIM "Lean" constructions is more of a construction management style that plans, optimizes and streamlines a project. At 4D BIM, we do the same with 9D BIM.The difference is that we are required to do this management method. BIM 9D reduces construction costs and activities that do not give value to the final deliverable, but the same can be done in the 5D BIM, which is referring to cost planning.

BIM 10D refers to the industrialization of construction. This is a very interesting aspect and leads to evolution. We currently use vertical and horizontal elements in 3D models, pillars, beams, walls and slabs.

Through the industrialization of construction, we imagine a central library where companies add all the materials used on the market, and designers use them in projects much more efficiently. The result would be to work directly with three-dimensional digital elements to design constructions.

We propose to do an exercise of imagination and transform BIM 9D from "Lean" construction into BIM 9D aesthetics and project visualization.

To do this we need to define very well what aesthetics means in architecture and construction. The aesthetics of a building is one of the main aspects considered in architecture.

The attraction and beauty of a building cover the combined effects of shape, size, texture, colour, balance, and proportion, space, alignment, pattern, decoration, the culture and context of a building.

From this simple definition we can see that it is absolutely necessary one of the five senses that Aristotle described about 300 years before Christ. This sense is sight, visual perception, or what we see with our eyes.

From this hypothesis was born the idea of BIM 9D to merge the aesthetic part with the visualization of a project.

Fig. 9. Final external rendering (source: Personal portfolio)

4. Conclusion

The new BIM 9D dimension-aesthetics and visualization of construction projects should include an aesthetic guide to be transformed into minimal standards. Three types of architectural visualizations should be integrated into BIM 9D: three-dimensional rendering, video presentations and virtual reality.

The advantage is that these presentations can be made with a simplistic model from the concept phase, and to achieve the most realistic results, a detailed model at LOD 300 level of detail is required, see [7]. *Through BIM 9D - aesthetics and visualization of construction projects we can also make a project marketing strategy.*

This can be very useful for developers because their project can be promoted from the design stage in the BIM environment.

Our study model, the individual home, has a level of detail between LOD 200 and LOD 300, see [7].

There was good coordination between the architectural model, the structure model, and the terrain model that has complex geometry. With a sufficiently detailed model, we were able to get some visual images close to what will be built in reality.

Project aesthetics and visualization can become a new dimension of BIM and we launch this challenge for BIM developers.

References

[1] ConectaBIM, About Bim - www.http://www.connectabim.com/about-bim/, p. 1-2
[2] Autodesk (2013). About BIM. http://usa.autodesk.com/building-information-modeling/about-bim, p. 2-3
[3] buildingSMART (2012). The BIM Evolution Continues with OPEN BIM. http://www.buildingsmart.org/organization/OPEN%20BIM%20ExCom%20 Agreed%20Description%2020120131.pdf, p. 2-3, 34
[4] openBIM (2012). OpenBIM - Programskrift. Stockholm.Northumbria University, Ryder (2012). Bimacademyhttp://collab.northumbria.ac.uk/bim2/?page_id=500, p. 2-3
[5] Northumbria University, Ryder (2012). Bimacademy http://collab.northumbria.ac.uk/bim2/?page_id=500, p. 2-3
[6] Biblus https://biblus.accasoftware.com/en/bim-dimensions/ p. 6-25
[7] LOD United-BIM https://www.united-bim.com/practical-approach-to-level-of-detail/, p. 18-25
[8] Empower Bim Technology, https://engbim.com/ p. 18-25
[9] PMI, Project Management Institute (2008). A guide to the project management body of knowledge p. 26
[10] Messner, J. (2011). Utilizarea BIM http://www.bim.psu.edu p. 27-34
[11] RICS 2013, Building Information Modelling for Project Managers, p. 35-37.