

# BIM Model Supporting Quantity-take-off and Construction Planning

Alcnia Zita Sampaio, V. F. Fernandes, A. M. Gomes

**Abstract**—The Building Information Modelling (BIM) methodology emerges as a concept with potential to reduce the fragmentation of the working mode in the construction industry, bringing a comprehensive integration perspective, reduced risk and making it possible to study the entire life cycle of an enterprise using a virtual and centralized information model. The selected case study considered in the research, supports the demonstration of the main benefits in using BIM methodology and software associated in the design and construction of a building. In a complete project, various disciplines are normally involved, including architecture, structure, water supply and drainage systems, electrical installation and excavation works. Other related task are also normally elaborated over the project information, namely, formwork of the structural elements, quantity-take-off of materials and planning the construction process. Concerning a study case, all these activities were supported on the BIM model generated with all the required disciplines, and complemented with the additional required actions. The objective of the work is to demonstrate the multivalences of the BIM methodology when applied on the developments and coordination of projects in construction. The present study also promotes the use of BIM-based tools within the integration and collaboration within a project team. The study contributes positively to the dissemination of the innovative methodology in the construction sector namely in manage and coordinate a BIM multi-project.

**Keywords**—Construction, 3D BIM, 4D BIM, quantity-take-off, coordination, integration.

## I. INTRODUCTION

Construction activity is a fragmented, complex and somewhat uncertain process. This sector is often referred to as having low productivity due to the loss of information between sequential tasks, outdated construction practices, ineffective coordination on the construction site, poor communication between the owner and the contractors. This in turn influences the profitability of a given project and the quality of the final product [1]. Recently, there has been a growing concern on the behalf of governments to encourage this sector to adapt to a process of digitalization in order to speed up activity and make

The report produced, in 2017, by Mckinsey & Co. [3], indicates that in the U.S.A., the construction industry has shown a progressive decline in its productivity since the

1960s, while other industrial sectors like agriculture and production have seen a significant increase (which, nowadays, is 10 to 15 times higher than in this period). The productivity of construction is strongly conditioned by the verification of incompatibility errors between projects, and when it is verified in the construction phase, it brings relevant additional costs. Such errors are caused by omissions in design as well as inconsistency between drawings, which then require rectification, adjustment and updating, further increasing the amount of time and money spent on the a given project [4].

In a building project the volume of repeated activities and correction caused by design errors are frequently responsible for about 20% of the total number of irregularities observed in the construction process. The quality of a project's planning process and the identification of inconsistencies and flaws within the designs and blueprints of the various specialties are determining factors in the success of the execution of the global project [5].

The implementation of the Building Information Modelling (BIM) methodology has been increasing efficiency in the construction sector [6]. NBS BIM report of 2016 [7], issued by the UK Institute of Civil Engineering (ICE):

- a BIM model is not only an improved geometric version of a CAD model, but it is also associated with improving information management;
- it supports the entire lifecycle of a building, integrating all the information involved in the development of multiple projects;
- as well it streams the communication between technicians and delivering services.

The main objective of the present study is to demonstrate the potential of the BIM methodology in accurately planning construction tasks [8]. This research study involves various modelling projects of different specialties related to a case study. Modelling software (Revit, Autodesk) was used to detect inconsistencies between various disciplines. Furthermore, a BIM viewer (Navisworks, Autodesk) was used to generate a 4D simulation model of the execution of this construction project

## II. THE BIM METHODOLOGY

For Sacks *et al.* [6] BIM methodology must be digital and three-dimensional, measurable (quantifiable and scalable), comprehensive (allowing multiple tasks to be performed), accessible (to all partners) and updated (maintenance and permanent update). Following this, BIM is supported on a

parametric modeling process that allows to create projects, in a BIM virtual model representation, with information incorporated, forming a data base organized allowing an easy accessibility to it and updating along the designing, construction and operating of a building [9]. The use of parametric objects which represent construction components such as walls, pillars or tubes, constitutes the fundamental characteristic of the modelling. The parameters are naturally geometric, but also have behavioral qualities, such as the thermal and acoustic resistance or the density of the materials. The information included in the BIM model is obtained through the modeling process based on the use of parametric objects and the data transfer between steps is based on the use of universal data file formats [10].

The ability to efficiently transfer data is where the concept of interoperability resides. Interoperability is supported by native software formats and universal data formats. The level of understanding between software is understood as the capability of different systems to communicate. To stimulate this connection, a consortium established between several entities involved in the standardization process, was created the International Alliance for Interoperability (IAI), responsible for the definition and disseminate of the International Foundation Class (IFC) format as a universal data standard. The language used in .ifc objects considers the establishment of designations and characteristics of parameters but also of procedures, rules, and restrictions.

Efficient interoperability between systems makes it possible to reduce the need to duplicate information and correct transferred data by facilitating the integrated workflow. The Mc-Graw Hill Construction Report (2014) [11] highlighted that 79% of BIM users in the US reported that the lack of effective software interoperability is still the biggest obstacle to adding the value of BIM in the sector. Succar [12] presents strategies to increase the maturity of BIM use in construction companies. Several stages must be implemented gradually, causing progressive changes. The stages are designated by:

- Prior BIM - Documentation in bi-dimensional (2D) representing a three-dimensional (3D) reality. Obtaining a map of quantities, costs and specifications from technical drawings composing the graphic documentation.
- Stage BIM1 - Creation of BIM models in three phases of the building's life cycle - design, construction or occupation. Use of BIM processes only for the generation and coordination of 2D documentation, but with a 3D view. There is no exchange between disciplines in an integrated digital way, with collaboration between asynchronous and unidirectional parties.
- Stage BIM2 - Participants in each discipline of the project collaborate mutually and actively. Collaborative exchange can be established between projects (architecture and structures), design and construction (structural elements and steel specification), between design and management

(architecture and maintenance plan). The level of detail required is high, but communication between participants is still asynchronous.

- Stage BIM3 - Integrated semantic models are created that are shared and maintained in collaborative mode throughout the project lifecycle through the use of Software as a Service (SaaS). The BIM manager is responsible for providing the experts involved who use the systems via the Internet. Interdisciplinary models are used in parallel by the different collaborators under the coordination of the manager. The collaborators are then able to manipulate all the information contained in the model for the realization of different types of analyses (energy or sustainability). The intended goal for this stage is to achieve an integrated project delivery process with the complete integration of users and systems, the purpose of improving the final product, reducing waste and increasing efficiency throughout the lifecycle of the enterprise. This stage corresponds to a full consolidation of the BIM in the Technological, Political and Processual (TPP) field, named, iBIM.

Regarding the benefits of adopting the BIM methodology, the most relevant in any activity is to achieve a reduction of global costs [13]. However, although the BIM methodology is currently the main innovative tool in the construction sector, there is still some resistance to its implementation. But the academy have been contributing positively to the teaching and dissemination of BIM in updating curricular programs, offering short professional and master's thesis courses and supervising masters in BIM issue [14]. In the educational area, the BIM adoption is slow but progressively it have been incorporated in civil engineering and architecture curricula [15]. The barriers are political, procedural, technological, labor and human. Traditionally, the construction sector does not immediately adopt new technologies, due to the initial investment required and the necessary staff training. In the review of current projects funded by the European Commission it Charef *et al.* [16] found:

- barriers that are acknowledged by all countries irrespective of their level of BIM adoption;
- barriers have been already tackled by the early adopters but not by the newcomers who have yet to experience some of these issues and finally;
- the assessment of the disparities of BIM adoption within the EU can help the European Commission towards unifying European standard on BIM.

### III. GENERATION OF THE 3D BIM MODEL

The building case study selected for the generation of the BIM model, touristic complex located in the interior of Portugal. In academic context, just a block was analyzed. The building consists of 4 floors: two-story building are half-basement, used for rooms, living room and kitchen and above ground level, the garage, rooms and attic room. The construction site presents a slope of about 30%, which

required a complex geotechnical work (Fig. 1).



Fig. 1. Location and 3D geometric model of the touristic complex buildings.

The main stages of the modeling process of the architecture, structure, mechanical, electrical, and plumbing (MEP) fields to design building systems and coordination and management disciplines are presented. The enterprise responsible for the construction did not use any BIM tool, having ordered only the final representation of the project, a 3D geometric model using AutoCad.

#### A. The architectural and structural components

The BIM 3D model is composed of the distinct disciplines that were considered in the present study. All technical drawing of the projects of the distinct disciplines and related task were provided in order to allow the execution of the present research work. For the modelling process the Revit (AutoCad) system was used.

First, the architectural component was modeled using the parametric objects allowed in Revit's library. Each element, found in the architectural menu, was selected and adjusted in order to allow a realistic representation of the building. After the structural component was modelled based on the drawings of the structural project consulted. So, in order to realistically replicate architectural and structural components such as walls, windows, floors, columns, beams, and foundations were found in the respective library and adopted to the built case in geometry, composition of layers of materials and mechanical and physical proprieties. In modeling process several simplifications were adopted as well some challenges had to be overcome and suitable to model adequate alternatives. A first stage of the BIM 3D model was then created following the procedure carried out that led to the complete generation of the specialties analyzed Fig. 2:

- Initial settings - The received architect designer blueprints were simplified, imported as *dwg* file from Revit, facilitating the modelling of the walls, the project units was replied and the organizing the project browser was setting with the levels and grids required for the 3D modelling. The topography was also creates

as well the surrounding elements based also in information allowed by the build owner;

- Architectural component – From the lowest level towards the top there were created initially the walls, the floors and the roof and after there were added the doors and windows in each level. The following modelling steps concerned the insertion of stairs, railing, ramps and distinct components located outside of the house;
- Structural components – working over the architecture, an independent model was created concerning the structural components. For that, the family of concrete elements was loading and each selected element was adjusted to the real structural project. There were inserted columns, structural slabs, isolated and beam foundations, and in order to allow the quantity-take-off (QTO) of the rebar, the model was complemented with the reinforcement of each structural element. The reinforcement menu accessed in Revit provides this capacity.

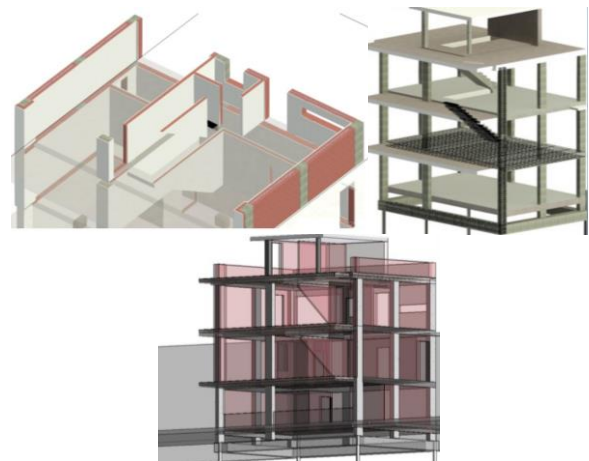


Fig. 2. Architectural model, structural model with reinforcements and structural and architectural overview.

#### B. Water supply and drainage systems

One of the benefits frequently mentioned by users of BIM-based technology is the facility that the MEP systems can be developed, supported over the architectural and structural models. A menu of Revit concerning MEP has the capacity to define the ideal pipe routes, thus allowing to work with millimeter tolerances, avoiding many incompatibilities and errors during the construction of the building. The steps necessary to model the water project are (Fig. 3).

- Initial settings - Loading the pipe families, establishing the routing preferences and setting the plumbing fixtures according to the 2D documents;
- Hot and cold water supply system - Adding the horizontal pipes, connecting the pipes vertical shafts with the horizontal ones, connecting the water system with the fixture;
- Domestic wastewater drainage system - Adding the pipes vertical shafts, connecting the pipes vertical shafts with the horizontal ones, connect the plumb system with the

outputs of the fixtures, guarantee enough inclination in the horizontal pipes to allow the flow of the system.

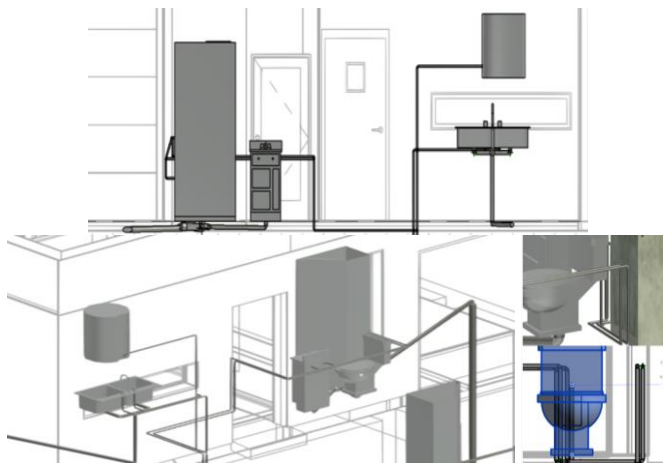


Fig. 3. Model of the water systems.

### C. Electric net system

Another component of the BIM model was created, also over the components previously modeled. The elaboration of the electrical component of the BIM concerning the electrical power grid design is more complex and less intuitive. For the generation of the electrical distribution systems, it was necessary to previously define the voltage values and locate the electrical panels in the building. The selected electrical frame was positioned in electrical equipment, and *m\_lighting fixtures* and *balanced power connector 220V* were selected from the library, considering the required elevation related to the positioning of the false ceiling, where the lighting equipment is inserted. The receptacle *m\_duplex top switched standard* sockets were selected and properly positioned on the walls.

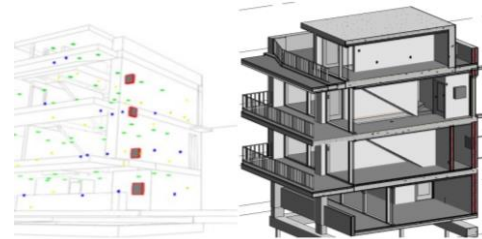
The place on *vertical face options* were used for the placement of the sockets and the *place on face* option for the location of the light focus, using the view of the false ceiling plan (Fig. 4). This indication allows a connection between the sockets and the lamp focus to the 220v panel. However, it is advisable to create the connection between the equipment by tracing cables, and for this purpose, one-way arched cables were used to connect the most distant foci to the panel of each floor. Thus, when the *power* option is activated, the distribution system is generated. The sockets, in turn, go through the same connection process, only the cables are located closer to the walls.

Finally, the *door-m\_lighting* switches are placed, which are extremely simple. They are used for the interruption and connection of the complete electrical current of the space in which it is inserted. After its placement, through *switch system* → *aad to system*, the desired lamp foci are chosen and an identification is assigned to the switch. In this case, identifications with the name of the spaces, garage, living room, w.c. floor 0, etc. were adopted (Fig. 4).

Hidden Line	Name	Value	Minimum	Maximum
General	1	220	220,00 V	220,00 V
Angle				
Wiring				
Wire Sizes				
Wire Types				
Voltage Schedules				
Distribution Systems				
Cable Tray Schedules				

Name	Phase	Configuration	Wires	L-L Voltage	L-G Voltage
1	220V	Single	None	2	None



<Electrical Fixture Schedule>		<Electrical Equipment Schedule>	
A	B	A	B
Family and Type	Level	Family and Type	Level
M_Duplex Receptacle - Top Switched - Standard	T1	M_Single Phase Panel - 120V MCB T1	
M_Duplex Receptacle - Top Switched - Standard	T1	M_Single Phase Panel - 120V MCB Piso -1	
M_Duplex Receptacle - Top Switched - Standard	T1	M_Single Phase Panel - 120V MCB Piso 0	
M_Duplex Receptacle - Top Switched - Standard	T1	M_Single Phase Panel - 120V MCB Colobreira	
M_Duplex Receptacle - Top Switched - Standard	Piso -1		
M_Duplex Receptacle - Top Switched - Standard	Piso -1		
M_Duplex Receptacle - Top Switched - Standard	Piso -1		
M_Duplex Receptacle - Top Switched - Standard	Piso -1		
M_Duplex Receptacle - Top Switched - Standard	Piso -1		
M_Duplex Receptacle - Top Switched - Standard	Piso -1		
M_Duplex Receptacle - Top Switched - Standard	Piso -1		
M_Duplex Receptacle - Top Switched - Standard	Piso -1		

<Lighting Fixture Material Takeoff>		
A	B	C
Family and Type	Level	Material Name
M_Lighting Fixtures/T1		Default Light Source
M_Lighting Fixtures/Piso -1		Default Light Source
M_Lighting Fixtures/Piso -1		Default Light Source
M_Lighting Fixtures/Piso -1		Default Light Source
M_Lighting Fixtures/Piso -1		Default Light Source
M_Lighting Fixtures/Piso -1		Default Light Source
M_Lighting Fixtures/Piso -1		Default Light Source

Fig. 4. Selection of the electrical fixtures and model of the electrical fixtures and table of devices.

### D. Formwork of the structural elements

Prior to the time simulation of the construction planning using the Navisworks software, the steps related to the formwork of the structural elements of reinforced concrete was analyzed and modeled (Fig. 5). This complementary activity, required in the elaboration of a real project, enrich the present simulation study of the construction process. The structural elements were used to model the formwork and periods of application were associated. The formwork elements were modeled considering as walls elements made of wood and with temporary periods of permanence in the model. In the construction simulation these elements are visualize in periods. Berlin walls were also modeled.



Fig. 5. Formwork of the structural elements and berlin wall to support the excavation work.

### E. Model of the soil excavation

In the case study, a volume was created in the deployment



region, through the functionality. It is a 3D configuration followed approximately the shape of the volume of land to be excavated. The *in-place mass* function allows to design non-regular shapes. It requires the indication of the line tracing on the surface of the ground and at the base of the excavation to be performed and following create *form* → *solid form* operations, resulting in the definition of a solid or mass that is delimited by the lines. In this case, the first step to the definition of the contour of the volume of the earth to be excavated, *mass object*, was considered a reference plane perpendicular to the levels. The excavated amount of soil was modelled from a *mass in\_place* which is ideal for unusual geometry elements. It is modelled through topographical lines which generate planes and, when combined, form a mass that can be quantified (Fig. 6). The volume of excavated can then be calculated and presented as quantity-take-off of earth requiring to establish the constructive stages and control the shipyard of the construction local.

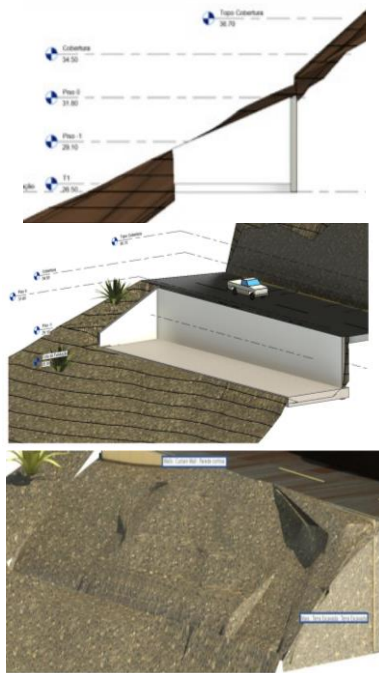


Fig. 6. Representation of the excavated work.

#### IV. COORDINATION OF THE PROJECT

All specific tasks can be considered within a BIM environment. The clash detection between systems and models support the project manager to coordinate the design, the construction process and the quantity-take-off of materials.

##### A. Quantity-take-off of materials

One of the greatest benefits, often recognized among professionals BIM user, is the possibility of automatically quantify divers type of components of the model and materials. In the main Revit interface and through the *project browser* menu, the *schedules/quantities* option is selected. Over the structural component of the BIM model it is possible to extract

tables of quantities of the concrete elements. The user must select the type of table to be created (concrete) including the indication of the desired parameters (material, volume, floor). Fig. 7 presents a list of the material, *structural concrete in situ*, and the type of element in which the material was applied (beams, columns, slabs).

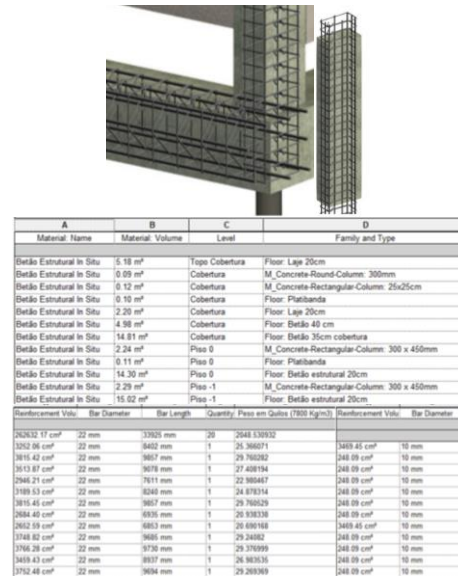


Fig. 7. Detail of the model of the structural and tables of concrete volume and bars.

The table shows the entire volume ( $m^3$ ) of concrete estimated for the building. This kind of quantity-take-off tables can be obtained, by element type, by zone or by floor, and the amount of concrete volume per floor or construction phase can be estimated. These values can be after used to establish estimation cost by construction phases or financial tranches. Related to the structural component, the quantification of the formwork area ( $m^2$ ) and the weight of the reinforcements ( $Kg$ ) were also required. To estimate the formwork quantity, a new table was created, and as the procurement of areas is not carried out in a direct way, on the volume of the formwork elements, modeled with a thickness of 3cm and with an assigned material of wood, a column of calculation is added. The amount of bars identified by diameter was also obtained. One more parameter was added to the parametric objects applied in the modeling process, the average steel density ( $7800 kg/m^3$ ), so that the mass ( $kg$ ) of the reinforcements could be obtained (Fig. 7).

##### B. Clash detection between components

Using the BIM view, Navisworks (Autodesk) system, an analyses of conflicts between disciplines was performed. The *clash detective* tool is highly valued by designers and contractors for identifying inaccuracies between different disciplines in the design and preparation phases. In the case study, errors were detected which were subsequently corrected in the BIM model by resorting to the Revit system once again, as these types of corrections should not be performed in Navisworks (Fig. 8).

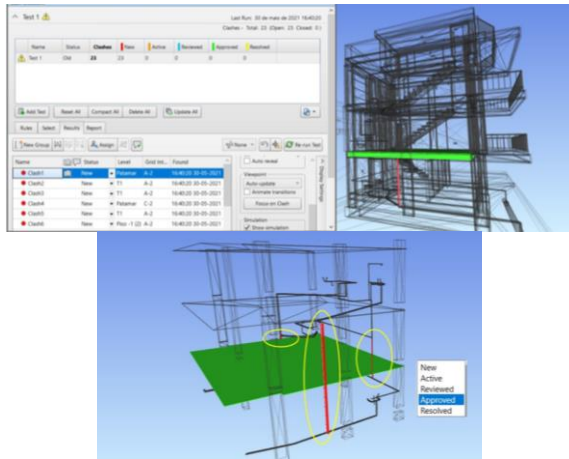


Fig. 8. Report of the clash detection analyses between the wastewater system and the structural component.

As this case study is relatively simple, the existing collisions are easy to solve. However, when the range of disciplines is larger and include architecture, structures, MEP, HVAC, fire safety and telecommunications projects, the task of conflict analysis brings important benefits. When carried out in the embryonic phase of the project, the planning of activities becomes more reliable, and the execution time of the work became reduced.

### C. Generation of the 4D BIM model

Using again the Navisworks viewer the simulation of the construction process was performed. Previously it is necessary to proceed with the planning of the construction, considering the identification of each activity and the associated chronology. To this end, the applicable national regulatory documentation was consulted, and planning was established through the project management software, Microsoft Project. Subsequently, the BIM model and the file drawn up in the planning software are transferred to the, and the modelled building elements was associated with their activity. The 4D BIM model consists of construction planning, considering the identification of each activity and the associated chronology.

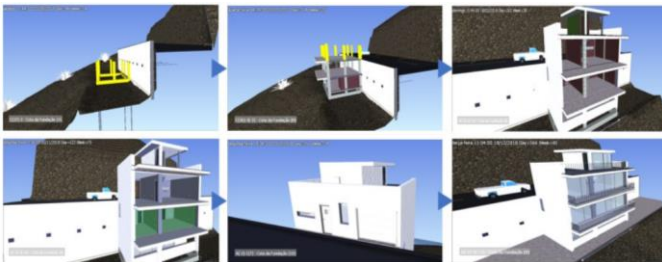


Fig. 9. Construction simulation screenshots.

## V. CONCLUSIONS

The implementation of BIM methodology can be incredibly valuable to the construction market. The greater degree of assertiveness and higher quality of design and construction planning (based on the parametric modeling process) leads to a

more controlled use of technical and human resources. The greatest advantages observed in this study, were the possibility of overlapping different models (architectural, structural and MEP), eliminating possible conflicts between disciplines, creating a realistic visualization of the interior and exterior (3D perspectives in sections) and attaining a better understanding of the complexity of placing elements in the same building. Moreover, estimating the quantity of materials through take-off material spreadsheets provides a more accurate estimation of construction costs. Finally, the 4D model makes it significantly easier to plan construction activities during the conception of the project. During the execution phase, it helps ensure the correct implementation of the activities supporting the coordination and management of a project. However, being an innovative methodology, the BIM tool requires a long, exhaustive and detailed training period. Finally, another drawback was the difficulty in finding objects that faithfully represented the context of the national civil construction.

## REFERENCES

- [1] M. A. Milyutina, "Introduction of Building Information Modeling (BIM) Technologies in Construction", *Journal of Physics: Conference Series*, 2018, <https://iopscience.iop.org/article/10.1088/1742-6596/1015/4/042038>
- [2] A. Z. Sampaio, "Maturity of BIM Implementation in the Construction Industry: Governmental Policies", *IJETT- International Journal of Engineering Trends and Technology*, ISSN: 2231-5381, Vol. 69 (7), pgs. 92-100, doi:10.14445/22315381/IJETT-V69I7P214, 2021, <http://www.ijettjournal.org/archive/ijett-v69i7p214>
- [3] McKinsey report, 2017, <https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/mckinsey-quarterly-2017-number-1-overview-and-full-issue>
- [4] R. Volk, J. Stengel and F. Schultmann, "Building Information Modeling (BIM) for existing buildings - Literature review and future needs", *Automation in Construction*, 2014, vol. 38, pp. 109 – 127, ISBN 0926-5805, <https://doi.org/10.1016/j.autcon.2013.10.023>, <https://www.sciencedirect.com/science/article/pii/S092658051300191X>
- [5] W. Lu, A. Fung, Y. Peng, C. Liang and S. Rowlinson, "Cost-benefit analysis of Building Information Modeling implementation in building projects through demystification of time-effort distribution curves", *Building and Environment*, 2014, Vol. 82, pgs. 317-327, ISSN 0360-1323, <https://doi.org/10.1016/j.buildenv.2014.08.030>, <https://www.sciencedirect.com/science/article/pii/S0360132314002893>
- [6] R. Sacks, C. Eastman, G. Lee and P. Teicholz, *BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers*, 3<sup>rd</sup> Ed., ISBN: 9781119287537, DOI:10.1002/9781119287568, 2018 John Wiley & Sons, Inc.
- [7] BIM Report, 2016, NBS International BIM Report 2016, <https://cis.ihs.com/cis/login?accessionNo=313806>
- [8] V. F. Fernandes, "Analysis of the capabilities of BIM technology in the generation of 4D models" Master thesis in construction, University of Lisbon, Lisbon, Portugal, 2021.
- [9] W. Mohammad, W. S. Abdullah, M. R. Ismail and R. Takim, "Overview of Building Information Modelling (BIM) adoption factors for construction organizations", *ICONCEES 2017 - 4<sup>th</sup> International Conference on Civil and Environmental Engineering for Sustainability*, IOP Conference Series: Earth and Environmental Science, 2017, Vol. 140, Langkawi, Malaysia, <https://iopscience.iop.org/article/10.1088/1755-1315/140/1/012107/pdf>
- [10] L. Araújo, "Development of a wall library in BIM methodology", Master thesis in construction, University of Lisbon, Lisbon, Portugal, 2016.
- [11] SmartMarket Report of McGraw-Hill, "The business value BIM for construction in major global markets: how contractors around the world are driving innovation with building information modeling". McGraw

- Hill Construction. President Keith Fox & Vice President Katherin E. Cassino, 2014, [https://icn.nl/pdf/bim\\_construction.pdf](https://icn.nl/pdf/bim_construction.pdf)
- [12] B. Succar, “Building information modelling framework: A research and delivery foundation for industry stakeholders”. *Automation in Construction*, 2009, Vol. 18 (3), pgs. 357-375, ISSN 0926-5805, <https://doi.org/10.1016/j.autcon.2008.10.003>.
- [13] A. Z. Sampaio and B. G. Antunes, “Quantity Take-Off Process Supported by Building Information Modeling (BIM) Methodology”, book: *Sustainability and Automation in Smart Constructions*, 2020, Ch. 4, pp 21-28, Advances in Science, Technology & Innovation, Springer, Cham, [https://doi.org/10.1007/978-3-030-35533-3\\_4](https://doi.org/10.1007/978-3-030-35533-3_4)
- [14] A. Z. Sampaio, “BIM education required in construction”, book: *Sustainability and Automation in Smart Constructions*, 2021, Ch. 1, pp. 3-9, Advances in Science, Technology & Innovation, Springer, Cham, [https://doi.org/10.1007/978-3-030-35533-3\\_1](https://doi.org/10.1007/978-3-030-35533-3_1)
- [15] R. V. Lozano-Díez, O. López-Zaldívar, S. Herrero del Cura and P. L. Mayor, “First experiences in the rule of the BIM environment: The case of the degree in Building of the Polytechnic University of Madrid”, *Advances in Building Education: Educative Innovation in buildings*, 2018, 2 (1), 109-121, <http://polired.upm.es/index.php/abe/article/view/4233>
- [16] R. Charef, S. Emmitt, H. Alaka and F. Fouchal, “Building Information Modelling adoption in the European Union: An overview”, *Journal of Building Engineering*, 2019, vol. 25, ISSN 2352-7102, <https://doi.org/10.1016/j.jobee.2019.100777>.

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