BIM in Architecture Process: Cost Management

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ABSTRACT

The construction industry plays an important role in any national economy and, according to a study published by Delloite (2018), there is a consensus that there is a link between a country's economic growth and its investment in construction. For example, the Canadian construction industry employs more than 1.3 million Canadians (7% of the active population) and it is expected that the global construction industry will have a weight of 4.1% in total global GDP (Gross Domestic Product) from 2017 to 2035.

At a time when sustainability is becoming more and more legislative, and in light of this, the present dissertation examines how BIM (Building Information Modeling) technology contributes to the reduction of waste of resources and, with more focus, on cost management in architecture projects and their budgeting.

Starting from describing fundamental concepts to the understanding of this theme, like cost, budgeting, expense and price and comparing the traditional methodology with the BIM one, this research strips the weaknesses of the still current practices of Project that influence the budgeting, cost and control of construction, and how BIM can respond to this problem.

This study also has a case study where a Bill of Quantities (BoQ) is created in Revit, making use of the Cype and Excel tools, that is to say through the BIM methodology, in order to compare the results with an existing budgeting of the project in question, made through a traditional technique by a specialized company.

The results of both measurements showed a negligible deviation (~ 1%), so we can infer the reliability of the automatic measurement results from the model, which is positive, since it means that both the Revit model and the Measurements are correct and consistent.

However, reflecting through a more comprehensive view, it was found that with BIM a budget (partial) was achieved, with only a few “clicks” in the software. Through traditional methodology time would undoubtedly be much higher. "Time is money" and in this light, it can thus be concluded with the present study that a project process developed in BIM presents great advantages compared to the traditional methods in the direction of cost control, in view of the calculation and reliability of the obtained results and the drastic reduction of time invested.

INTRODUCTION

The building industry alone is responsible for up to 50% of the European resources extraction (European Commission, 2011*)* and having an actual impact of approximately 4% on the global GDP (Delloite, 2018), it becomes of extreme importance the need of precise and advanced cost control, thus the current dissertation presents itself as a study of the potentialities of BIM (*Building Information Modeling*)software in the budget control of architecture projects.

According to Innes (cit. in Osmani, 2004), about 33% of material waste in loco is caused by the incorrect implementation of waste reduction measures by architects during the project phases. Also, the precarious communication between entities during these design stages leads to the piling of errors and bad overlapping of the project specialties. This is due to the fact that the “flow of information is made in paper and electronic files in 2D format, produced separately by each intervening entity throughout the process” Ferreirinha (2017: 34).

This traditional methodology in the AEC (Architecture, Engineering and Construction) Industry is becoming increasingly inefficient to respond to the current AEC Industry requirements, as new approaches promise better results. This is the case of BIM software, which will be reviewed here and compared to the traditional methodology in an effort of baring its advantages in the control of construction costs.

CONSTRUCTION COST

In this first chapter, important concepts are grasped, such as concepts of cost, expense, and price in the context of the AEC industry. The understanding of these concepts is fundamental for the elaboration of this investigation and the analysis of the proposed objectives.

The first to be approached is cost: In the AEC industry, the word "cost", according to Oliveira, L. and Perez Junior, J. (2000), is the value that refers to the goods and services that are consumed in the production and/or production of other goods and services , such as the cost of building materials used in a construction site, the purchase or rental value of machine equipment to perform a certain task during

construction, and the payment of the salaries of architects and engineers who rendered services to the project.

The cost of a building can be classified into different types, of which the most important are:

The “direct cost” which consists in “all expenses directly and exclusively incurred in the execution of a work” (Henriques, P. 2017), the ones which can be quantified, identified and measured in the budget map of the work, such as directly productive labour, construction materials, equipment directly linked to productive operations and general yard charges;

The “indirect cost”, according to Henriques P. (2017) “does not directly affect the execution of the various activities that constitute the work, such as the expenses [...] of the structure of the company.", i.e. insurance, financial expenses, expenditure on the headquarters of the construction company, advertising, etc. These overhead costs will not directly integrate budgets, but in most cases, they are considered as a proportionate share of direct costs or profit.

The next concept to be described is “expense”, which, according to Castro, J. (1997), does not represent a physical cost like materials, equipment, labour, etc., but rather, those that contribute to the work itself and are indispensable for the accomplishment and its operation and are not represented in the project budget list, such as the assembly and dismantling of construction sites, mobilization and demobilization of construction materials, etc.

The last concept is the “price”. While costs are all the values that the contractor needs to perform the production of a work, the price is the value of the market sale of the finished work (Best, R. et al. 2009).

BUDGET

This chapter comprises a brief description of what the budget is and how it influences the cost control of construction. It may be defined as a monetary estimate of the sum of the direct and indirect costs of the execution of the work (Dias, P. 2011), plus the profit margin defined by the construction company or contractor, and determines an estimate of the final price to be proposed (González, M. 2008). The budget also allows the development of a programmatic system in relation to labour and materials for each task of the construction process.

As It was said, it is an approximate estimation of the total cost of the construction, but it also comprises imprecisions and errors. Avila, A. et al. (2003) alleges that these margins of error can build up to 15-20% in a budget made during a preliminary project, in which not all the necessary information for an execution plan is available. Mattos, A. (2006) affirms it is indispensable to study all the stages of the execution of the work, to interpret correctly and to analyse in detail the drawings as plants, sections and elevations, (elaborated by traditional methods or extracted from a BIM model). He adds that a profound knowledge of the different specialties of construction and the experience of who does it are central to a correct budgeting.

Essential to any Bill of Quantities is the measurement of quantities materials and services. According to Sabol, L. (2008), the measurement of quantities by traditional methods is a process that is not only tedious but very intensive and time-consuming, indicating that this process may require between 50% and 80% of the time and work in budgeting. In addition to this process, it requires a lot of care and attention from the manufacturing technician and it is subject to human errors, whether it is manual or computer measurement. Badra, P. (2012) affirms that an usual increase of 10% in quantities is accounted as to ensure the profit of the company as a result of unforeseen and measurement errors. This can be a preponderant factor for the non-realization of a large project, which is still a barrier of traditional methodologies.

BIM METHODOLOGY

The transition from the hand drawing of the technical drawings to the use of CAD represented a great revolution in the process of architectural design. Several barriers were exceeded but the representation remained much the same. Despite including three-dimensional elements, we did not have significant improvements in other aspects, the methodology of design continues to be the superficial representation of objects, be this dimensional or three-dimensional, and the final result remained practically the same.

Through the demands of the market, an idea of modelling the elements that make part of a construction and work with all its dimensions appeared, and so did BIM.

The definitions of BIM by the consulted authors mainly converge on the idea that information can be obtained from the whole life cycle of a building, from a three-dimensional model that contains associated information created through a tool, BIM software. This is an evolutionary process, an *m.o.* that consists of the execution of a parametric model that gathers geometry, spatial relations, geographical information, quantities and constructive properties of each intervening specialty, allowing to integrate the several specialties in a single model, used to demonstrate all the life cycle of the building, including construction processes and installation phases. It also allows you to identify and correct collisions, interferences, errors in the design phase and automatically obtain quantities, details, cuts, views, elevations, characteristics of materials and costs in their construction phase.

After describing the concept of BIM, this chapter proceeds on explaining some fundamental concepts of BIM software, like BIM Dimensions, LOD (Levels of Development) and IFC (Industry Foundation Classes).

BIM brought various advantages to the AEC Industry, and this study highlights:

Its virtual representation of a real construction, which can be analysed by all the collaborators at any time in all its 7 dimensions.

Its interoperability, as it permits the collaboration between several designers of different disciplines, based on a reliable central model, which is constantly updated and made compatible with the reception

of new files, consequently, the documents produced are much more coherent and precise, reducing the project time, errors and omissions (Doumbouya, L. et al. 2016).

One other advantage of BIM tools is the parametric modelling and automatic production of documents, since the BIM models are elaborated with elements or families parameterized according to the Classes. This allows any modification made in the model to automatically change the associated elements (Eastman, C. et al., 2011). From measurements, areas, volumes and quantities, to factors that influence cost, energy efficiency, sustainability and maintenance, etc.

According to a research from Baroni, L. (2011, cit in Braga, P. 2015), "80% of users claim to have reduced errors and omissions in documentation; 71% also identify reduction of work; 71% say that the BIM model helps to reduce the cycle of specific flows of certain activities, especially drawing; 62% said that BIM helps the company to offer new services to customers; 51% agree that the concept also serves as a marketing tool to attract new customers and increase the company's competitiveness; 49% said that BIM increases the profit of their business."

Looking at the main objective of the present study, BIM also presents specific advantages in the budgeting process and control of the cost of work.

According to Eastman et al. (2011) in his BIM Handbook, you can export the quantity measurement from a BIM software to a budgeting software. BIM also has the possibility to connect itself directly to an extra budgeting software, that is, to include BIM in the budgeting process, either through the installation of a plug-in or through tools developed by third parties like Cype. These budgeting softwares rely on data bases that usually contain the most current materials on the construction market and suffer regular updates. They may also contain the necessary resources such as manpower, equipment, materials and associated costs and time. As a result, all the information required to develop a complete Bill of Quantities and a detailed list of the basic activities can be used for construction planning.

This chapter continues on listing some of the existing BIM software, like Revit (because of it popularity and its use in the case study towards the end of this research), explaining the concept of Revit Families, and Cype as it includes a very complete data base of price references relative to the building materials, and Excel, due to its important role as a complement to the Bill of Quantities.

BIM ON PROJECT CONTROL

BIM methodology favours an improvement in the quality of buildings, making significant contributions in all phases of the life cycle of the building, from design, design, construction to operations and maintenance after construction. The proper use of the information contained in the project model contributes to the better control of the integrated activities of the project, as well as the compatibility between the different specialties, construction management, maintenance of the building and reduction of time and cost of construction. Thus, this chapter will focus on the level of control BIM can bring to the practise of Project in its various phases, namely:

“Previous Control Before Project” refers to all the tasks and preparations that need to be previously performed such as the collection of all information and documentation necessary for the project, as well as the location and plan of implementation, the geographic features and topographic plan, information on infrastructure, water and drainage, condition of contiguous buildings if any, characteristics and designs of the building existing in case of rehabilitation, etc. This tends to be a time-consuming exercise and this process can be lightened through the junction of BIM and Laser Scanning technologies.

Also, during the Previous Studies, it is normal to make studies and analyses on the feasibility of the project. Among these, the forecast of the cost of construction is one of the most difficult to determine in this stage, due to the lack of information, however, this research found that through the BIM methodology it is possible to estimate, with some approximation, the actual cost of the work if the BIM Families used for the construction carry information on the properties that are integrated and parameterized in order to be quantifiable. This shows the importance of having correctly parameterized families as soon as possible.

The next phase to be identified is the “Control during Project Design”. Here some ground rules for modelling and structuring of base model information in BIM software are established as a measure of control amongst the various designers. For Callegari, S. (2007), the control and management of the project is in the minimization of errors, in the optimization of processes, in the reduction of costs and in the compatibility of projects. The literature shows that a great amount of errors come from poorly designed technical drawings, which tends to happen when complex projects are made through traditional methodology, which, in turn, usually implicate loss of time and/or money. Theoretically this won’t happen with BIM methodology, as any changes to the modelled objects or families loaded in the project propagate to all their instances so it may perform automatic updates with smarter change control (Eastman, C. et al., 2011).

Another issue studied in this subchapter is the poor communication between the different specialties of a project and the frequent dissociation between project documentation which happen in traditional methodologies. According to Kymmell (2008), the exchange of information among all the entities involved in the project is based on a unique model, in which the information of all specialties with automatic update is aggregated. This avoids conflicts between documents, reducing time and cost, thus optimizing process and project quality.

Finally, on this subchapter, other advantages are reviewed such as the database that allows BIM to extract different drawings of a project model automatically. Other advantage is the automatic change throughout the model and all the documentation if a change on some construction elements are to be made. This feature saves a lot of time and money and contributes significantly to control the cost and deadline of the design process, compared to a traditional design process.

During the “Control Before Construction/ During Execution Project” phase, technical and final documents are essential for the planning and cost control of the execution of the construction. One major aspect of planning is time. This planning comprises the improvement of the schedules through the control of deadlines, continuous flux of constructive tasks, etc.

According to Florio, W. (2007), the BIM methodology contributes to the integration of the information in a 4D digital model, which allows a verification of the constructive elements in detail and to analyse the sequence of the tasks for execution having in mind a better control of the planning of operations and orientation of the professional technicians in the work.

This planning results from the different simulations of execution of the work through the BIM model in 4th dimension, the temporal dimension, in order to look for the best tasks sequences over time of the construction process.

Alongside the BIM 4D, in 5D BIM, the documentation automation also applies to project quantities extraction and to obtain the total or partial Bill of Quantities map in a quick way. 5D BIM allows the designer to have greater freedom in improving the project at any time and at the same time comply with the deadlines and budget.

The level of control BIM has in the building cycle goes on through its “Construction Phase” and even after it, during its use. According to Meireles, A. (2015), the value of the operation and maintenance of the building after construction can reach about 80% of the total cost of the building, which draws an increasing interest in taking advantage of BIM 7D for asset management, cost reduction of operation and maintenance of the building, as well as the control of the quality of building components.

CASE STUDY

This chapter consisted on establishing a comparison between the BIM methodology and the traditional one in budgeting and weave some conclusions about the possible differences between them.

Using a Revit model from a real Project, a review and correction of the model was required, in order to avoid the influence of previous modelling errors in all the process. The second step was to turn it into a 5D Model in order to extract the Bill of Quantities (BoQ) and respective costs with the aid of Excel and Cype. Then, a comparison is made between this BoQ and the one already made by the specialized company using a traditional method of quantities take-off. This comparison can be demonstrated through the following table:

	Quantities takeoff by Revit	Bill of Quantities
Walls in concrete masonry unit of 50x20x25 cm	94,20 sq.m	94.63 sq.m
Walls in concrete masonry unit of 50x20x20 cm	302,50 sq.m	303.00 sq.m
Walls in common brick of 30x20x11 cm	182,43 sq.m	184.04 sq.m
Walls in common brick of 30x20x7cm	40,39 sq.m	44.51 sq.m

CONCLUSION

The AEC industry, due to the complex nature of its processes and the large number of players, is one of the industries which still lacks budgetary and deadlines control. In this sense, the emergence of digital technologies has made it possible to search for new avenues so that construction processes tend to be executed efficiently, without wasting time and cost. The need to develop a greater number of auxiliary tools and technologies imposes a change in the mentality of the interventions in the design, construction and maintenance process. The appearance of CAD tools changed the way the building was designed and represented in the last quarter of the 20th century. The Building Information Model (BIM) opens the door to a paradigm shift in the way it is designed.

From the case study experience in which the measurement results obtained through Revit and Cype are practically equal to the values of the Measurement Map made by the specialized company, we can infer the reliability of the automatic measurement results from the model, which is positive, since it means that both the Revit model and the Measurement Map are correct and consistent.

However, reflecting through a more comprehensive view, in addition to the numbers in the BoQ, with BIM a (partial) budget was achieved, with only a few clicks in the software, and even adding the revision time of the model, this turned out not to be considerable. Otherwise, through traditional methodology, first, it would not be so easy to do, and the time would undoubtedly be much higher. "Time is money." And in this perspective BIM, in the eyes of research, has a great advantage that is the efficiency of the design process.

It can thus be concluded from the present study that a project process developed in BIM presents high advantages over traditional methods in the sense of cost control, due to the calculation and reliability of the results obtained and the drastic reduction of the time invested.

As a future path of development of the present research, it is challenging to elaborate an exhaustive study of more than one case study in order to test exploration hypotheses that allow us to conclude about the role of BIM in controlling and optimizing project costs.

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