Construction management supported in a BIM model:
Practical case study applied to an energy recovery center from solid waste

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Abstract

The industry of Architecture, Engineering and Construction (AEC) has sought new methods to increase the level of organization of the different tasks, supported in the use of a wide range of software. However, most of the available tools have two major limitations, which BIM seeks to overcome: the ability of interoperability between systems and an adequate structure of the data required in different processes, namely a chronological sequence of data generation and an easy and methodological access to enterprise information.

The developed study evidence on the review of a case, that frequent anomalies in work may be reduced in the construction management when is supported by the methodology Building Information Modeling (BIM). The selected case study refers to a central energy recovery from solid waste in which its construction management was conducted with the help of traditional methods. In order to compare this type of management with a BIM methodology, were identified real situations and proposed a resolution supported by these new tools. Following these intentions, the developed BIM model, which included the buildings on the contract, as also several specialties, namely, structures and building networks. On the model defined from the work of production planning strategies, effected up changes as the chronological reception of the projects of the various products and those from the monitoring of ongoing work.

This work aims to contribute to the dissemination of knowledge and practice of BIM methodology, focusing on the development of the construction.

Keywords: Building Information Modeling (BIM), Construction, Construction management

1. Introduction

Throughout the building construction cycle are present fields of architecture and engineering, contributing, with their specificities, to carry out the design process, construction, management, operation, maintenance, use and demolition or reuse of the building (Tardif & Smith, 2009). These fields have constantly sought working methods that increase the organization's quality in the performance of tasks, supported the use of a wide range of software. However, most of the available tools has two major limitations, which BIM seeks to overcome: the ability of interoperability between systems and proper organization of data required during the different processes. (Singh, Gu, & Wang, 2011).

The construction management is based on digital drawings, volume and tasks maps. During the construction process frequently occur changes in the execution project, requiring the modification of the final design and subsequent tasks, which should be updated accordingly. In this context, the BIM concept contains all the information inherent to the various project components, which can be updated after new phase or alteration, and is the appropriate support for streamlining the management of a work (Tardif & Smith, 2009).

The thesis proposes the analysis of a case study, with the perspective to analyze advantages and limitations underlying the implementation of BIM in construction. The selected case study was coordinated by the author in the construction manager status. This one focuses on the problems inherent in the production of a construction, detected in real case situations, and compares the resolution made in traditional models with the BIM methodology. It is developed the modeling of different design specialties, is introduced upgrading of each component, according to the changes imposed on the initial project, are identified conflicts of incompatibility between model components and presented resolutions in BIM environment.

2. Building Information Modeling (BIM)

The BIM methodology has the ability to encompass numerous functions and verify the implementation of norms and regulations throughout the development of design, construction and later in operating activities and property management. The basic concept is to admit that all parties should contribute to the core model and develop the several project components from it (Figure 1) (BuildingSMART UK, 2010). Interoperability capability, inherent in BIM, enables the improve of collaboration among members from an interdisciplinary team belonging to construction site, allowing better quality in the interaction of projects based on an exchange of data between different applications and platforms, allowing the execution of integrated projects and allowing free exchange of data across different applications and platforms (Figure 2) (McGraw-Hill.Construction, 2007).

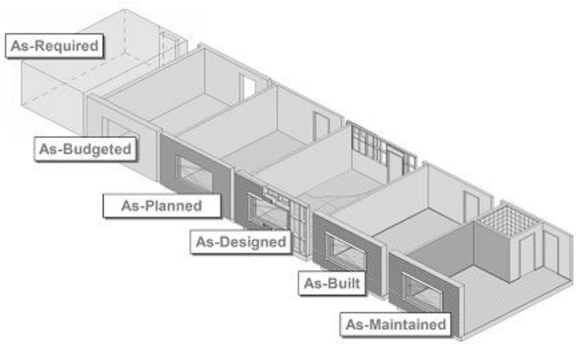

Figure 1 – Building information coordination (Tardif & Smith, 2009)

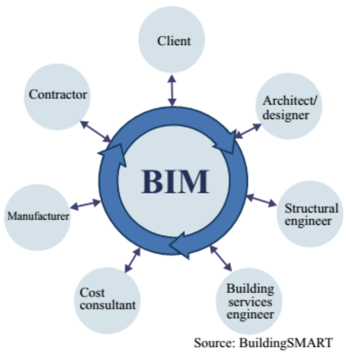

Figure 2 – Participants of the information model (BuildingSMART UK, 2010)

Some general benefits that characterize the BIM applications are: excellent communication between users, possibility of obtaining amounts of maps, clarity in the construction sequence, reducing the number of requests for information and change orders, introduction of unique data and reuse these throughout the project life cycle (BuildingSMART UK, 2010).

With the use of BIM, the model is developed using a high level of detail, in which physical interference are visible, with BIM applications that automatically detect conflicts. This space coordination reduces the work execution cost, allowing the detection and solving incompatibility before the construction. (Wang, 2012). This is translated by *MacLeamy Curve* (Figure 3). It mentions that the initial effort in developing the BIM project is high, but decreases over its production. He explains that the cost for obtaining a good quality is related to increased financial investment involved in the project, so there will be minor deviations from the initial costs due to errors and omissions design (Simões, 2013).

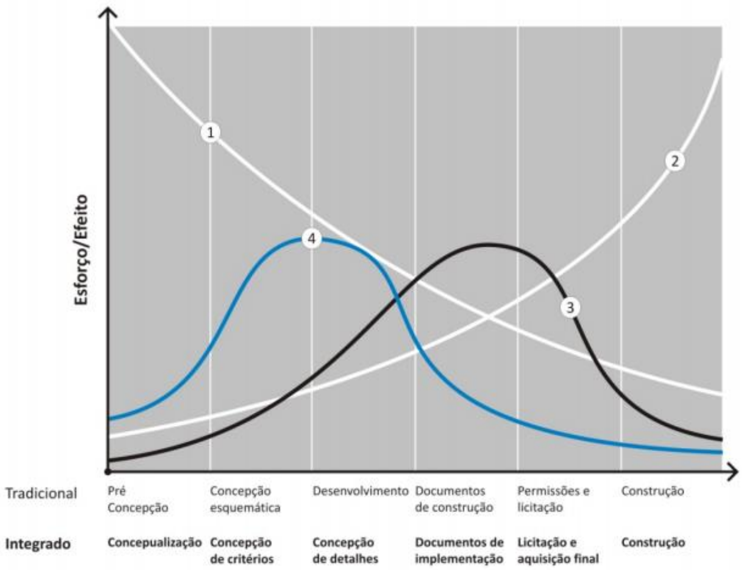

Figure 3 – MacLeamy Curve

Coordination in drawing up contracts

The design-build project delivery methodology (DB) was applied in the case of study, carried out according to traditional techniques, and have also been used in the development of BIM methodology. This methodology (DB) is a system where the building owner hire a single entity to the implementation of design and construction itself, under a single contract for design-build. This model guarantees the building owner a unique responsibility for the services of design and construction (Sanvido & Konchar, 1999). The IPD methodology is a project delivery approach that integrates people, systems, structures and business practices in a collaborative process, based on the ideas of all participants, which increases efficiency in all phases of a project lifecycle. Although it is possible to achieve IPD without BIM, studies recommend the use of this. (Eastman, Teicholz, Sacks, & Liston, 2011).

3. Case study

This chapter features the work from the case study, as to his context in the project and references aspects that will be focused in detail and analyzed in the following chapter, in a BIM perspective. Contextualizes, also, the construction management process in particular the documentation required in the planning and construction output. The case study is part of the present work as the example of the practical application of theoretical procedures, discussed in previous chapters. The focus of its development involves the construction management, with the use of BIM technology. The aim of this study is to analyze the various situations that were in fact found during the course of work on site, with the participation of the author, could have been resolved if the BIM methodology had been applied. For the case study was used as an object of study, a central energy recovery from solid waste. The construction management *in situ* was supported only with traditional tools. The construction discussed in detail corresponds to a part of the enterprise, in particular one of their buildings and the installation relating to underground network. This is part of the *redevelopment project of the municipal landfill of Terceira Island and energy recovery from municipal solid waste of the central group* (Açores, 2011). The contract consists of several built blocks that can be viewed in Figure 4 scheme.

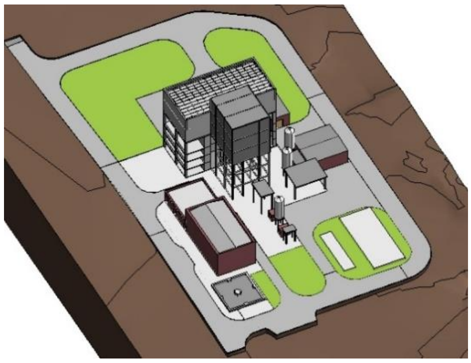

Figure 4 – Builts projections. The left figure show the plan. The right figure, the 3D projection

The study focuses on the follow-up case study of the planning and execution of construction of one building of the project and foundations of other buildings, with implications in the networks. The studied building was the building waste collection, called *Bunker*, due to its geometry. The building system has been carefully analyzed, since revealed to be having great influence in the construction progress.

Coordination in the project development

Construction projects have not been fully presented at the beginning, some have been delivered to the construction company only through the development of the construction, namely, the various changes that have been made by the designers and building owner, with the construction already underway. The delays that have occurred in the delivery of some of these, along with changes imposed, caused delays to the construction itself. In this context the way to solving some of the work processes were designed differently to initially scheduled. The construction company, prior to the start of work, hired an engineering design company, specializing in structures and building facilities, to carry out the review of projects. This created a "communication triangle" between the building owner, the construction company and the company hired to review the projects. This type of shared responsibility led to some conflicts, especially in terms of communication, which led to some delay in project delivery, generating some disagreement and complications in work.

4. Application of BIM model to the practical case

As part of a review in BIM environment was necessary to start the process for the development of the three-dimensional models (3D) required. For this purpose resorted to the use of *Revit 2015* tool, from *Autodesk* company. This version of the tool includes, in a unique interface, the functionality of the disciplines of Architecture, MEP and Structures (Autodesk, Revit Free Download, 2015). For the case study components of some specialties model was created. BIM systems support a combination of various components in the form of phase coupling. These tools have also the ability to detect conflicts inherent to the overlap of the courses. The resolution of each conflict situation is detected and resolved on the BIM model, in an immediate way. This chapter describes the various situations that occurred in the workplace and conducts analysis of its resolution on a BIM methodology base, using the capabilities of the software used.

Reception of projects

The owner of the building and the contractor for the project review, submitted projects in a phased manner, and not all together. As a result, changes were made to the planning of planned activities, on the development work in back office, and also in the progression of the work in situ. The *Bunker* building can be displayed in the created BIM, also its complete structure from the foundation to the roof, and also his development in all phases. About the other buildings, only were modeled the elements that make up the foundations, they are the ones that have interference with the development of building networks, aspect to consider in a BIM perspective.

Building networks

The working method of the project companies that developed this specialty is to design software based with the use of overlapping layers. However, the changes that have been imposed on foundations of buildings of the contract were not considered. The modeling of the networks on the representation of foundations was thus executed and settled by the construction company using the *AutoCAD Civil 3D* working tool. In a BIM process, the execution of the project of the building networks would be superimposed to the structure of buildings. Because the elements are delivered to the construction company, with the elements of the network components modeled with a high level of detail, during the project development. In addition, in the BIM collaboration environment, the construction company could be an integral part of those projects, according to the *Integrated Project Development* methodology (IPD). In the work developed model was also possible to fit along their phases, amounts of maps, input and deleting elements, changing slopes, coupling pipes, among other situations. The networks considered in the case study were: sewage, water supply network and power grid.

Conflicts

The modeling and integration of network elements in the BIM model is trimmed in parameterization of properties associated with modeled objects. Setting this property does not allow inconsistencies and provides rules with the ability to identify changes that violate the feasibility of the objects. The software used checks and alert for the occurrence of transgressions between objects, therefore, any errors that may appear in the construction are previously identified during the design phase, reducing the number of errors and additional costs. The preparation work of building networks on the basis of structure is a fundamental process that is performed on site, because changing the path of the tubing is constrained due to the presence of the structure elements. The analysis of the situation on the BIM model is done automatically. In the Figure 5 visualizes one of the conflicts identified during the development of the model, in this case, a conflict resulting from the interference between the pipe and a bunker foundation.

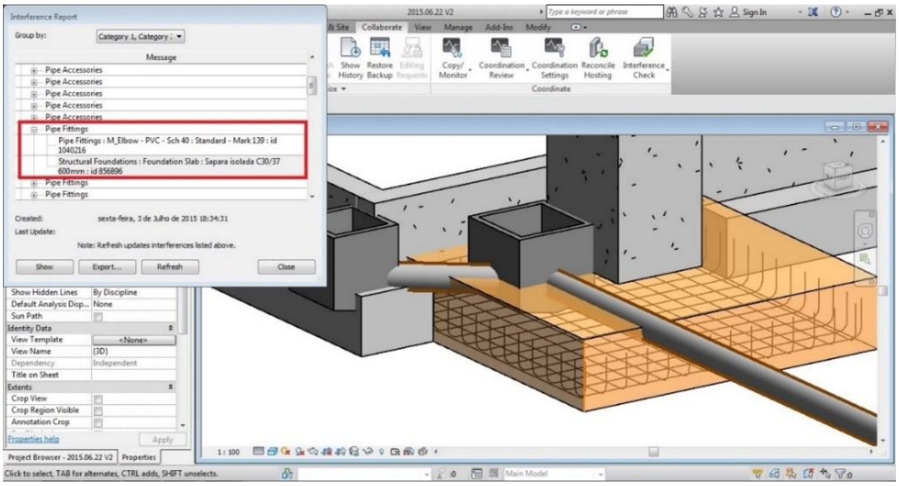

Figure 5 – Conflicts between a piping and a Bunker structural element

Subcontracting

This item show three cases of those activities which were carried out by subcontractors, confronting the solution adopted in work with its resolution trimmed by BIM methodology. These three subcontractors were: enforcement of building networks, execution of the formwork of the *Bunker* and cutting performance and molding reinforcement of elements in reinforced concrete. The development of building networks in the construction was the most critical work, due to the large number of uncertainties, errors, omissions and delays in several projects. Most of the changes made in the foundations of buildings had an impact on the network system. Stands out as one of the most serious, the situation found in boiler cover foundations, because there is a big cross of elements at the same location. The subcontract formwork was studied in this work to explain the actions that occurred in the slab formwork at elevation + 17.50m. Because of this level of the slab, the construction company resorted to using a truss. The volume completed by the truss and the area of the slab can be seen in Figure 6, where there are represented elevations of the BIM model.

The third subcontract refers to cutting and molding the reinforcement elements consisted on reinforced concrete, because these were also subject to constant change. Apart from these changes also occurred the initial situation of the projects armor does not exist in Portugal and the lack of armor on some elements of the projects. In Figures 7 and 8 is possible to observe changes occurring in the armor of the Bunker.

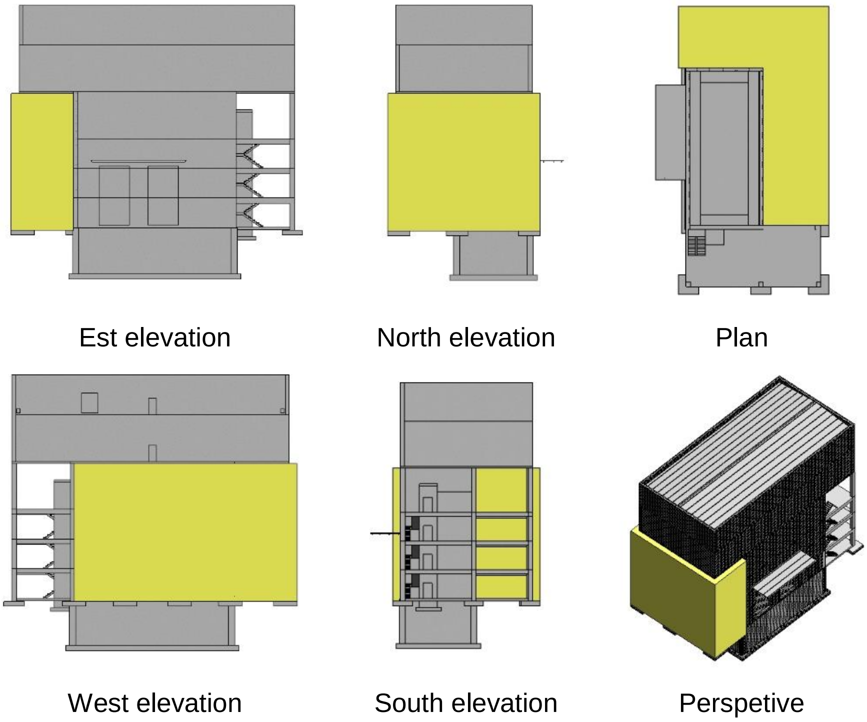

Figure 6 - Elevations, plan and perspective of the volume occupied by the falsework (yellow) for slab formwork

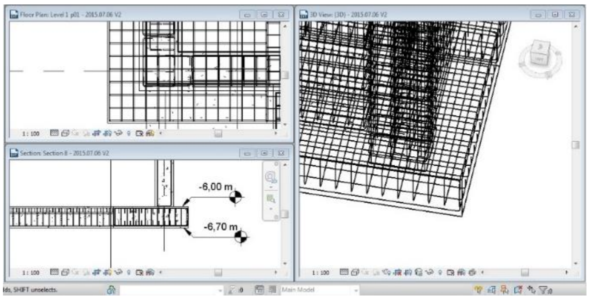

Figure 7 – First projects sent by the building owner

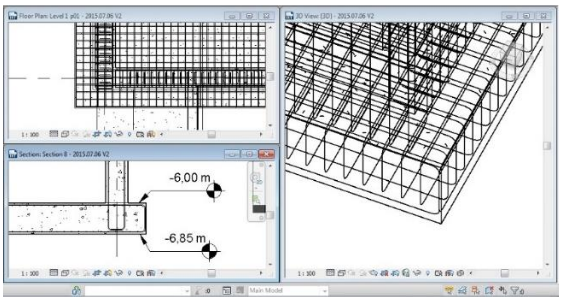

Figure 8 – Projects submitted by the team of optimization projects

Other project modifications were made when some works were already in development, such as changing the slab reinforcement at elevation + 17.50m, when much of this armor was already placed and ready to receive concrete. These changes lead to costs and delays in work. New cuts and armor modeling had to be executed and some diameters had to be modified.

Coupling elements

Changing elements, because they fulfill the same space in the same instant, it is a recurring situation in Design-Build project delivery, because while the work is in progress some projects are still being created. In the practical case occurred this situation, at least in one case. This led to one of the already implemented elements that had to be chopped in a certain area to allocate a coming slab foundation. In Figure 9 we can see the chipping area of concrete. Figure 10 shows the modeling of these foundations, in BIM.

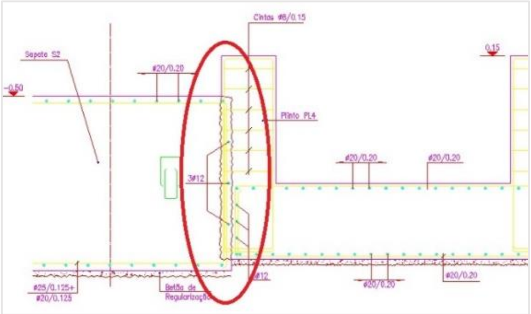

Figure 9 – Docking area of the two foundations, in a CAD drawing

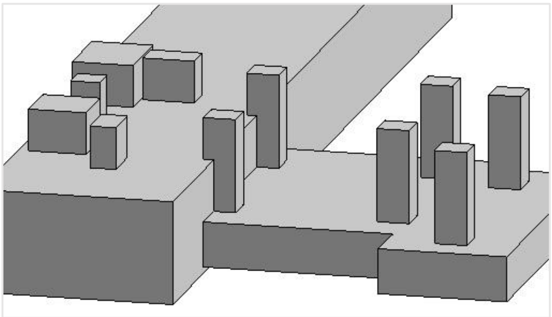

Figure 10 – Modeling of coupled foundations, in BIM

Interoperability for data handling

Interoperability between software has highly importance for the handling and processing of data. *Microsoft Excel* tool is considered the main application for estimating construction costs. Based on this knowledge and understanding the importance of other tools, BIM by enabling the extraction of amounts of maps, enables data to be exported to files in formats that allow the handling of data, using other tools. As an example, from the analyzed case was exported the quantities of maps obtained from building networks, having these been exported in a format to be used by *Microsoft Excel* tool.

5. Analysis of the results

I was proposed the use of BIM from the start, for the creation of masses to model the buildings. These allow a faster understanding of the work in progress and if it matches the goals proposed by all stakeholders in the project, especially the owner of the work. Also allowing the achievement overall values for the teams involved in their construction, as referred in the calculation amounts of several elements.

The working model *Design-Build* provides the progress of the work *in situ*, while several design works are still under development. However, this could create the need for subsequent changes made in elements already built. In the studied case some elements occupying the same space, causing changes to projects and looking for appropriate solutions. The agreement developed by the construction company with a new project team, in order to optimize the projects, was not satisfactory from the point of view of the work productivity, causing some disagreement with what was expected. The ability to perform various activities in a phased manner allows always store the information of the models previously executed. This enables retrieval information into disuse and obtaining amounts of maps for the various stages, providing the elaboration of comparative maps.

Subcontractors

The course of the work on site, developed by the subcontractors, was variously affected, because the projects did not keep the necessary updates in a timely manner. The errors, omissions and modifications, verified during the construction process, were situations which occurred frequently. The situation became more serious because the three subcontractors hired had direct interference between them.

The major advantages in developing the practical case related to building networks, both to the general contractor as the subcontractor is the following: Query tubes quantities of different materials; Demand of materials for immediate or phased delivery, in order to provide optimal control of the storage yard or warehouse; Demand of optimized prices, depending on delivery dates or volume of material to order; Drafting contracts with a number of proposals, for example, delivery of materials and construction works, purchase and placement on site.

The various changes occurring in the projects related to the thickness of the slab had special impact on the progress of other components of the work, such as centering and the building "boiler cover". The construction presented a high degree of complexity, and the presence of errors in work led to delays, more costs and the increase of complexity. All the modifications presented in the chapter *subcontracting* led to increased costs and increased time needed to hand-skilled labor. Also adds the influence of the contract, because the changes occurred led to increased costs, as well as, delays due to order of materials.

Drawing Errors

In the traditional work methodology the design error, namely the inconsistency between representations, occurs several times, because it is a human error, so it isn´t a automated or parameterized methodology. Although the design it’s a more depth study theme in project, in construction work it as a huge impact, such as the elements to developed in work to the subcontractors, drawing solutions to accomplish several tasks, space optimization among others. BIM model allow multitasks for those cases, with 3D visualization form all space that covers construction site, allowing the instant representation of several building sections, elevations and plans.

6. Conclusions

The work enabled the knowledge of the subject BIM. Research on the subject has exposed several objects of study covering BIM, from its origin to its application in the AEC sector, seeking to know the reasons for his development and how this methodology has been developed. The use of this methodology for the development of construction management emerged several situations that expose the benefits of using BIM.

Regarding the development of the case study, this showed the author that one of the great strengths of BIM, as well as various technical details of the created elements, is the development of their work in a cooperative manner, over the entire life cycle of a project. This situation is reinforced by IPD method, which brings together with the characteristics of BIM. However, this does not preclude the use of BIM in other forms of project management, as it turned its application in the case study developed at the methodology *Design-Build,* only boosts its use in the IPD model.

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