THE INTRODUCTION OF BIM METHODOLOGY IN EDUCATION
(Paper)
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Abstract
Teaching architecture requires a permanent updating of knowledge concerning procedures and technologies used in Construction industry. In this sense, a school of architecture should seek to adapt its curriculum to include innovative issues to support a better construction. The methodology Building Information Modelling (BIM), involving the concept of information centralized in a unique geometric model and of collaboration of all participants in a project, is strongly supported in advanced technology. An important role of teaching is to organize actions to promote the insertion of new issues in school. The text presents a curricular proposal with reference to motivation, contextualization, sequence of topics and pedagogical aspects. The objective is to add competitive skills in the training of future architects and civil engineers.

The BIM implementation covers various sectors of the construction industry. A BIM project constitutes a complete and full database, not only the geometric model, the most visible part of the process, but the materials applied in the building and its mechanical and physical characteristics. The methodology BIM interferes with all aspects involved in a building project: the initial stage of generation of the form (architecture), the different phases of the structural study (structural solution design, analysis and production of technical drawings), the quantification of materials and budgets, the construction planning process (definition of geometric model for each construction phase), or, later, the usage of the building (management and maintenance).

Several examples of BIM application were developed by the students in the context of the proposed discipline. Some topics are: BIM model analysis in the perspective of the structural project; Conflict analysis based in an architectural BIM model [1]; Maintenance of buildings supported in the model BIM, Coordination of construction project based on BIM technology [2]; BIM modelling in architecture and composition of parametric objects. Fig.1 shows some of the outputs related to the developed student works.
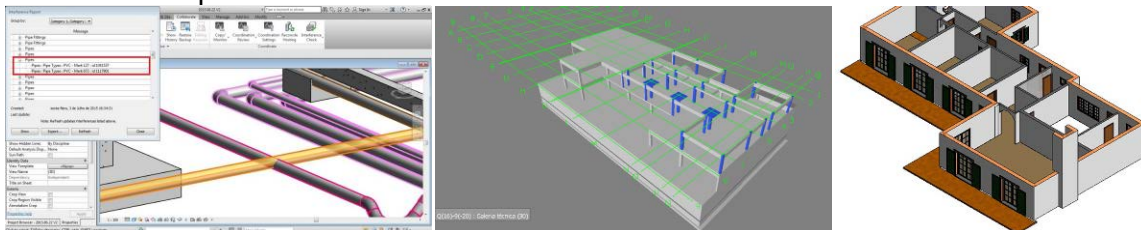

Fig.1: BIM uses – conflict analyses, construction planning and maintenance of buildings.

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Main References:
[1] Edgar Berdeja, "*Conflict analysis in a BIM based design*", MSc in Civil Engineering, Lisbon, Portugal, 2014.
[2] Claudia Mota, "*4D model for construction planning based on BIM technology*", MSc in Civil Engineering, Lisbon, Portugal, 2015

The Introduction of BIM Methodology in Education

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Abstract

Teaching Architecture and Civil Engineering requires a permanent updating of knowledge concerning procedures and technologies used in Construction industry. In this sense, the school should seek to adapt its curriculum to include innovative issues to support a better construction. The Building Information Modelling (BIM) methodology involves the concept of information centralized in a unique geometric model and promotes collaboration between all participants. An important role of teaching is to organize actions to stimulate the insertion of new issues in school. The text presents several examples of BIM applications developed by students in the context of MSc researches. Some topics are described in detail: 4D Model for construction planning based on BIM technology; Coordination of construction project based on BIM methodology; Conflict analysis based in an architectural BIM model. The objective is to add competitive skills in the training of future architects and civil engineers.

1. Introduction

The Building Information Modelling (BIM) methodology covers various sectors of the construction industry. A BIM project constitutes a complete and full database, not only the geometric model, the most visible part of the process, but the materials applied in the building and its mechanical properties and physical characteristics [1]. BIM interferes with all aspects involved in a building project: the initial stage concerning the generation of a form (architecture); the different phases of the structural study (structural solution design, analysis and production of technical drawings); the quantification of materials and budgets; the construction planning process (definition of geometric model for each construction phase); the usage of the building (management and maintenance), in a later stage [2].

In a more traditional process of developing a project, each player uses a different and non-integrated work methodology, as there is not a source of complete and updated information for the overall project. This lack of process integration is one of the main drivers for the loss of information and, causing a loss of value through each stage. Information is a key factor in management in the internal context, as well as the relationship with the exterior [3]. The evolution of the information technologies has contributed greatly with new possibilities of integration and communication at distance. In a sector, such as the construction, marked by the fragmentation and where multiple players exist, usually geographically disperse; this ability to communicate at a distance has been fundamental for sharing information. For that, it is also fundamental to ensure the interoperability amongst the multiple software solutions that are used in supporting the project development.

The BIM methodology, which combines the parametric design, three dimensional (3D) models, element level information, coordination, communication and visualization within the whole building lifecycle, is changing deeply the way how information is managed within

the construction sector [4]. The BIM concept aims at improving the work methods used nowadays. This new approach is based essentially in the integration of processes, supported by an information rich 3D model which allows to seamlessly tracking the whole lifecycle of the enterprise. As such, it is also expected that the whole process becomes more accessible to the multiple entities that collaborate in the enterprise either while developing the design and later in the management of the building.

In the context of the education activity in a Civil Engineering and Architectural school some topics of BIM application were developed by students within MSc researches. The main issue concerns the construction activity (Figure 1): The construction planning based on 4D/BIM models; Coordination and preparation of construction project using 3D/BIM models; Analysis of conflicts over an architectural, structural and MEP model.
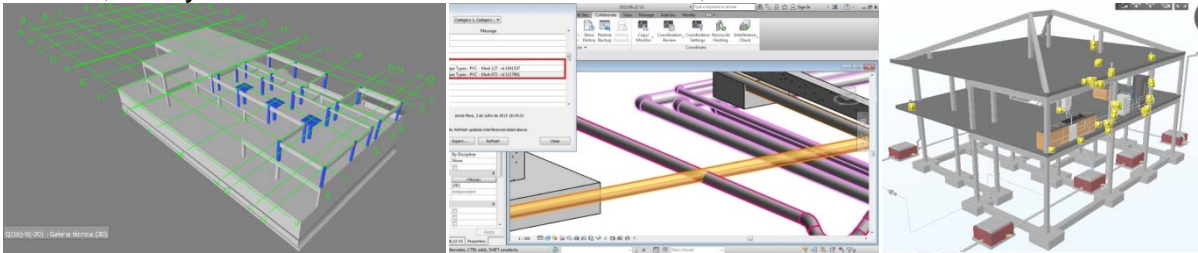

Figure 10: BIM uses – construction planning and coordination and conflict analyses.

2. Conflict analysis based in an 3D/BIM model

The BIM methodology and tools associated with it present themselves as an excellent asset to support the process of conflict analysis, as they make it possible to merge all disciplines in an integrated virtual environment, the 3D/BIM model. The high level of detail and visualization provided by a BIM model leads to a better collaboration between those involved throughout the design. The aim of the first study was to evaluate the practical capabilities of the BIM concept in the conflict analysis between building services, namely, the water supply and drainage systems design, and the architectural and structural design [5]. As such, it was developed a 3D/BIM model containing the components: architecture, structures and building services. The model was analysed oriented to the clash detection between elements from all disciplines.

2.1 Generating the 3D/BIM model

The house of the case study consists of two floors, with the ground floor comprising the garage and entrance hall and, the first floor containing the living room, kitchen, three bedrooms, two bathrooms, one utility room and hallways. In the generation process of the BIM model's architectural and structural components, all represented elements, such as walls, windows, doors, floors, columns, roofs and footings, were created by adapting the 3D parametric objects existing in the *Revit* library, in order to resemble closely the real case (Figure 2).
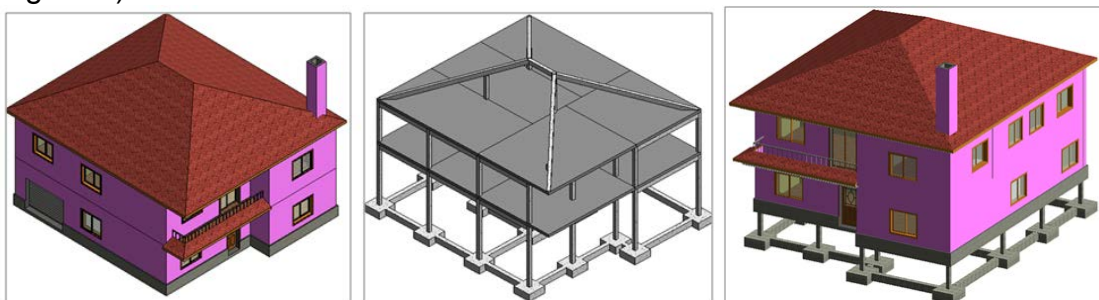

Figure 11: Architectural and structural components of the 3D/BIM model

Next, the MEP (mechanical, electrical and plumbing) component of the BIM model was generated, namely, the domestic hot and cold water supply system, the domestic wastewater system and the rain water drainage system (Figure 3). The modeling was initially performed solely based on the architectural component of the house, with no visual

guidance from the structural component. The architectural model was then supplemented with the plumbing fixtures. The piping diameters used in this work are approximate values of those present in the real design, for it was decided that the predefined nominal diameters from *Revit* were to be used.
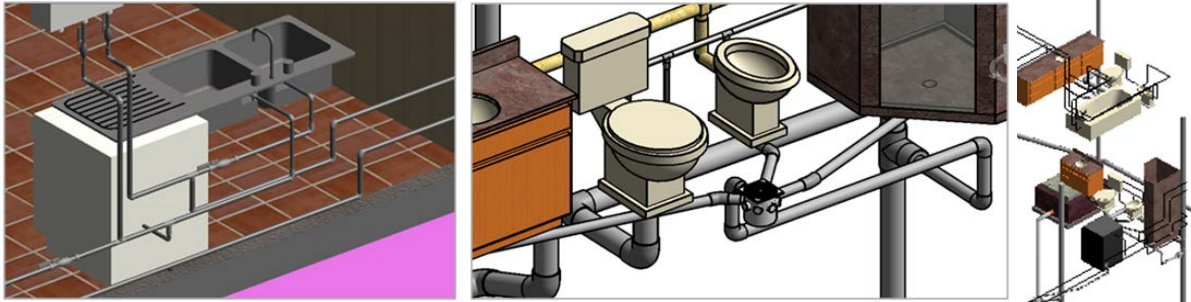

Figure 12: The water supply and the wastewater drainage systems of the BIM model.

2.2 Clash detection

The BIM modelling process requires overlapping multiple disciplines that coexist in an integrated manner, forming a complete model of the design. After each discipline is modelled forming a unique BIM model, the collision detection can be performed. Conflict analysis is an integral and very important part in the development process of a 3D BIM model. This process consists in searching objects belonging to different disciplines that are using the same physical space. The analysis of these inconsistencies is a critical task, since they could eventually severely impact the construction process, causing delays, design changes and increased expenses in materials and surpluses in the budget.

As a first step, the modelling of the MEP component was carried out using only the architectural component as guidance. That is, the structural component was not visible during the MEP modelling. After through the handling of the components structures and MEP, some of clashes were detect. Overlapping all the disciplines it is possible to change some of the elements of the MEP services, in order to obtain a correct model with no conflicts. Figure 4 presents some the realized changes needed to improve the complete 3D/BIM model of the house.
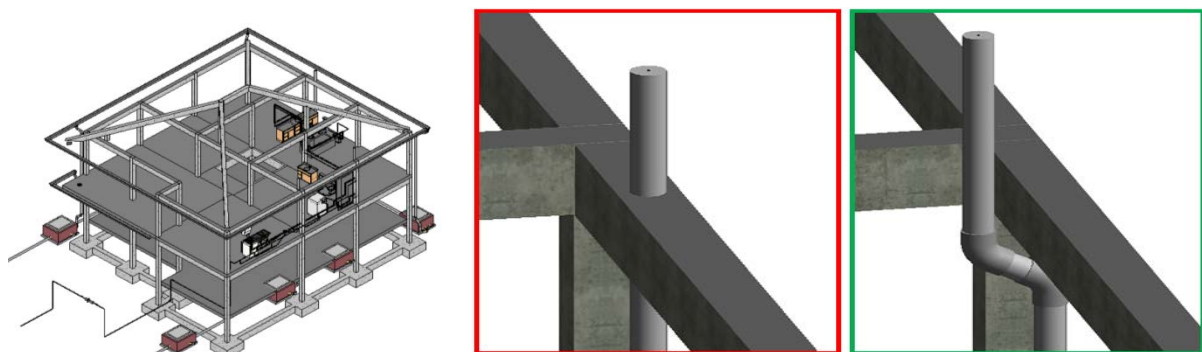

Figure 13: Coordination of structural and MEP disciplines.

The existing *Clash Detective* function in *Revit* is of great help in conflict analysis and project coordination. This work contributes to demonstrate the advantages of BIM in the conciliation and coordination between different specialties, as well as the benefits of its application in conflict analysis in an engineering design.

3. 4D/BIM model for construction planning

The planning of the construction activity is a crucial stage in the conception of a design, and involves the selection of technologies, definition of work activities, estimation and resource management, logistics and duration of each individual task, as well as all the dependencies amongst the different tasks. Planning and scheduling in construction, involves the sequence of activities both in space and in time, taking into account the allocation and resource acquisition, quantities and space constraints amongst others [6].

The estimation for the duration of the activities is a decisive stage for a good project and building planning, as the control of the schedule, depends on the proper effort and duration estimation [7].

3.1 Generation of a 4D/BIM model

In order to explore the BIM tools, as a support to construction planning, a 3D model of a second study case was first created. Using the *Revit* software only the architectural and infrastructure models of the project were generated. To create a 4D model the time factor must be linked to the 3D/BIM model elements. After, by running the defined 4D model, it allows the visualizations and analysis of the activity sequence for the construction. So, to generate the 4D model for the present case, the *Navisworks* software was used [8]. This software allows the interconnections amongst sets of 3D elements of the BIM model, with the planned tasks stablished in *MS Project* software. Briefly, the steps for the preparation of the 4D/BIM model are:

- Export the *Revit* 3D model, saved in the *NWC* format, to the *Naviswork* software as well as the *MS Project* planning file to the *Naviswork* timeliner;
- In the *Naviswork*, the 3D elements of the models were grouped according to the tasks defined in the planning. For this purpose, adequate "sets" were created. These "sets" can be created by selecting the elements directly over the model, by executing "tree selection" or by searching for its properties;
- Next the created "sets" were associated to the planning and schedule of tasks and set for each task its category, that is, whether it is construction, demolition, temporary activity or another.

3.2 Using the 4D/BIM model

By running the 4D/BIM model it is possible to visualize the planning simulation. Figure 5 shows a couple of frames, extracted from the simulation of this project.
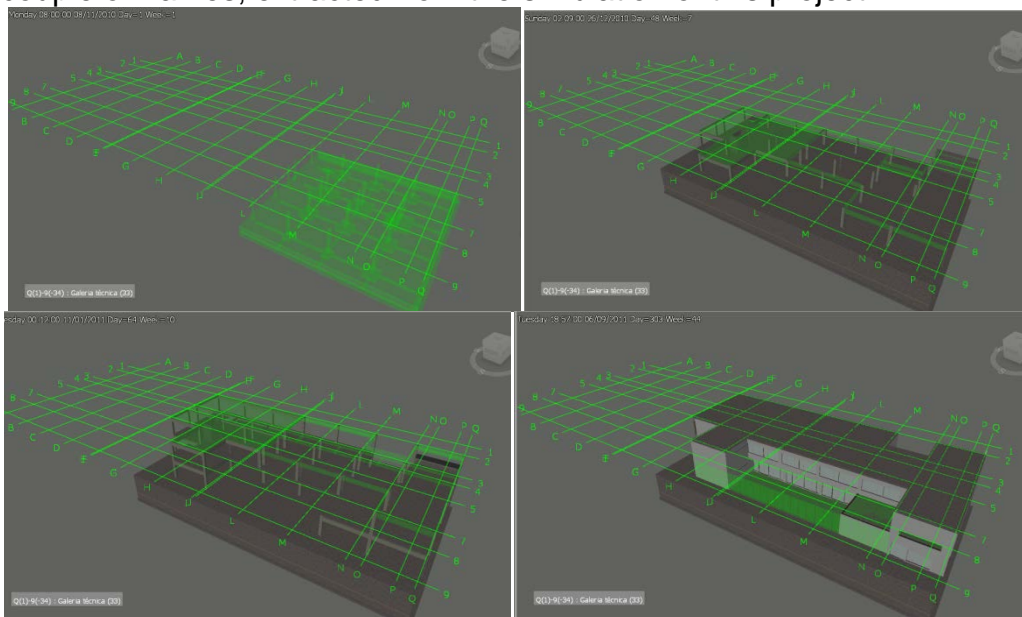

Figure 14: Construction simulation visualized in a 4D/BIM model.

The practical part of this work fell mainly in study of the 3D modelling using *Revit*, and applying a model for 4D construction planning. The simulation will probably never match the reality, with its unforeseen, but this motivates the development of visualization technologies, trying to reduce the gap amongst the digital world as the reality. The aim is to minimize the number of execution errors, at least those believed to be predictable.

4. Coordination of construction project supported on a BIM model

In a BIM process, the execution of a building project network would be superimposed to the structure of buildings. Because the elements are delivered to the construction company, with the elements of the network components modelled 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 this 3rd study case a 3D/BIM model was created. The model allow to support the coordination of phases of construction, the extraction of maps of quantities, the input and deleting elements of the model, to change slopes and coupling pipes, among other situations. The networks considered in the case study were: sewage, water supply network and power grid.

As part of the design review of this another case, it was necessary to start the process by developing the 3D/BIM model of the project [9]. This item 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 BIM software used.

4.1 Building networks and analyses of conflicts

The modelling 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. As mentioned, the *Revit* tool has the ability to detect conflicts inherent to the overlap of the objects. So the resolution of each conflict situation is detected and resolved over the BIM model.

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. Figure 6 presents 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.
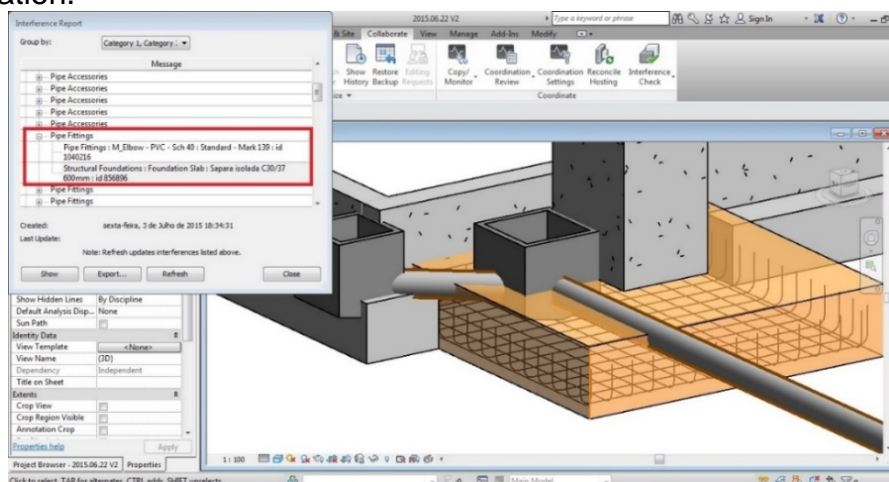

Figure 15: Conflicts between a piping and a bunker structural element

4.2 Coupling elements and estimative of construction costs

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. This led to one of the already implemented elements that had to be chopped in a certain area to allocate a coming slab foundation. Figure 7

(left) presents the chipping area of concrete represented in a *AutoCAD* drawing and Figure 7 (right) shows the modelling of these foundations, in the BIM model created.
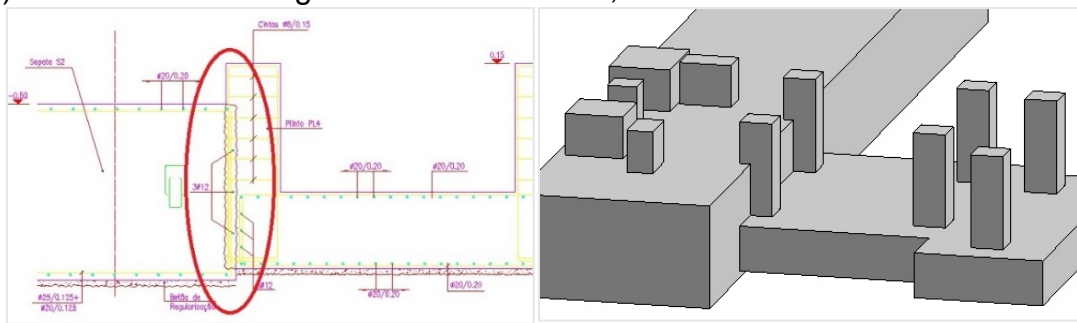

Figure 16: Docking area of the two foundations, in a CAD drawing and in a 3D/BIM model

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 this item 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. 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, *Revit* 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 (*Figure 8*). As an example, from the analysed 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.
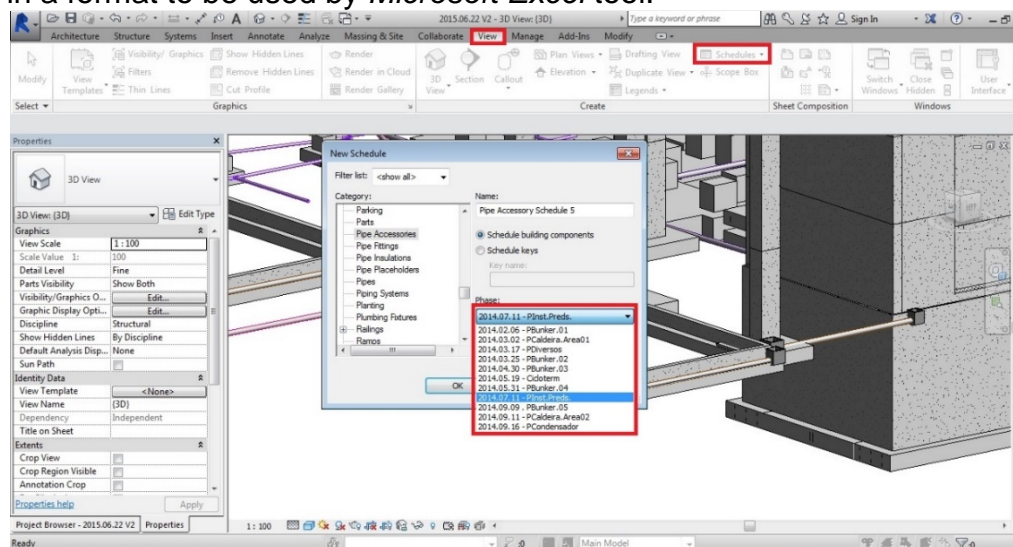

Figure 17: Selecting a quantity map by phases.

4.3 Technical drawings

In the traditional work methodology the design error, namely the inconsistency between representations, occurs frequently. 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.

5. Conclusions

The work enabled the knowledge of the subject BIM within a education context but oriented to the real activity. Research on the subject has exposed several objects of study covering BIM, from its origin to its application in the Construction 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.

Concerning the 1st study, an efficient conflict analysis was applied over a 3D model composed of architectural, structural and MEP disciplines. When comparing the BIM methodology with the *AutoCAD* usage, the representation of elements is more complete and its 3D viewing is immediate. In addition, the ability to simultaneously conciliate the architectural component with the structural component through the coordination view aids with obvious advantages the process of establishing a structural solution. Regarding the modeling of the MEP discipline, the entire pipe and complementary accessories modeling process was performed in order to accommodate them to architectural elements, especially walls and pavements. When comparing the applied process with the traditional *AutoCAD* methods, a big difference can be noted, with great benefits for the designer. The use of BIM tools as a means of conflict analysis presents an irrefutable advantage over traditional methods. The use of modelers, such as *Revit*, for this purpose enables a virtual visualization of conflicts with a very high level of detail. The conflict detection software are only a tool to help in the decision making process.

During the usage of the 4D/BIM model, some very positive points where found, from which the following ones are highlighted: The ability to visualize the schedule and the 4D simulation show that *Navisworks* can be a useful tool to support the project planning, in a collaborative environment, as intended in the BIM methodology. The schedule can be continuously displayed as it is generated and changed in a flexible manner; As *Revit* and *Navisworks* are both products from the same software house (*Autodesk*), the interoperability was found to be is very good. All the element data from the 3D models are also available in *Navisworks*; The possibility to use a workflow which includes 3D element parameters in the 3D model elements, similar to the respective tasks, simplifies the automated grouping through automatic selection rules; The ability to navigate through the model allows to analyse each corner and each location of this model or from a group. It also has the ability to export in many formats, in order to share the project data and the 4D modelling in mobile devices.

Regarding the development of the 3rd 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 construction process. This situation is reinforced by IPD method, which brings together with the characteristics of BIM. In this case it was analysed the improvement allowed by the BIM model and tools in the building network coordination, the analyses of conflicts between phases of the design, the way of coupling elements, how to easily estimative construction costs and to avoid error of inconsistency between representations.

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