Introduction to the BIM Methodology in Engineering Education

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Abstract: - The management of the totality of information concerning different phases of a building can be supported on a common environment. This concept is the basis of the technology Building Information Modelling (BIM). The text describes how the BIM concept has been introduced in the Department of Civil Engineering. The school itself has been promoting dissemination of BIM based on short training courses, seminars and technical sessions, involving credible designer offices and involving students in research projects, PhD theses and MSc dissertations. The basic BIM technology must constitutes one of the essential tools in student's training, helping them, in the future, to facilitate their integration in a demanding and competitive work environment.

Key-Words: - BIM Technology; Engineering education; Innovation in education

1 Introduction
There is now a growing interest in the adoption of Building Information Modeling (BIM) technology within the Architecture, Engineering and Construction (AEC) industry. A BIM model is a parametric model, strongly associated with visual presentation (the geometric model), but it is, in fact, a model rich in information [1]. The immediate benefit of BIM is that the three-dimensional (3D) model is automatically generated from the 2D lines drawn and the properties of the elements within the software. But, there is more to BIM than visualizations, as each building element is an object with its own information and identity.

Although is still at an early stage of development and implementation, the BIM is one of the most promising technologies for the integration of teams working on the same project. The ability for interoperability, that still must be made possible by BIM, is the basis of the integration of collaborators in the project [2]. Today, it is being used by many in the construction industry to make efficiency savings and to improve the accuracy and coordination of documentation [3], although it is still common for building information to be held in different models. For creating and handling a BIM model the user should acquire knowledge concerning the identification of data involved in each phase of the project, the analysis of its organization and classification and the study of modes of reuse and data depending on which additional phases are to be developed or coordinated for that model. The implementation of this concept involves multiple actors from different sectors of the AEC industry [4]. At present, the professional architecture and engineering community is embracing new technology quickly, incorporating new opportunities to streamline the design process and to save time and money [5], whereas the academic community moves more deliberately and thoughtfully to incorporate new technology and to offer new courses [6]. However, as the pressures increase both to control costs and save time, it is inevitable that Civil Engineering education will move into a world which demands that students and new professionals are adept at using tools like BIM.

The mission of the school of Architecture and Engineering is to prepare future professionals in those fields, and as such, must provide education on those topics relating to all aspects of those professions. As part of this, the school must focus on the changes in Information Technology (IT) tools, used in the project office which could be used in the realization of collaborative, interconnected and therefore more effective projects. For this reason, students need to acquire knowledge of basic BIM technology, both because it is innovative technology and because there is a growing interest in its application in the design office.

The text describes how the BIM concept is being introduced in the Department of Civil Engineering and Architecture, at the Technical University of Lisbon.
The school itself should promote dissemination in school, involving credible designer offices which already use, to a greater or lesser degree, this technology. This can be achieved through short training courses, workshops, seminars and technical sessions.

The next section, present the recent research at MSc and PhD levels, explore the training courses taught in the Department aimed at continuous training, as an extra-curricular service provided by the school and aimed at designers and architects who work in design offices. The final section refers to recent proposals for of research projects in the BIM field.

2 Bologna Master’s theses
BIM is changing the way projects are constructed. This emerging practice requires new mind-sets and technological know-how in order to achieve significant improvements in efficiency and cost control. At the Department of Civil Engineering and Architecture, the preferred target of education is the student as they are the future professionals. The student must acquire skills for using the advanced technology tools, as they will use BIM technology in their future activity; they will be thus more competitive.

Computer-aided drafting (Autodesk AutoCAD system) was for a time the most sophisticated modeling technique available to construction managers [6] but this is now giving way to the more complex technology of building information management. A school of Engineering and Architecture can be expected to constantly update computational resources in frequent use in the professions and to introduce innovative resources into the training of the student, leading to their adaptation for curricula in drawing and modeling disciplines. At the Lisbon Technical University, in Computer Assisted Drawing included in the curricula program of the Integrated Master in Civil Engineering, the adaptation has been gradual, accompanying the development of new graphics systems supporting plan drawing and modeling relevant to engineering activity. However, this strategy can be seen today as an old approach; the present perspective is aimed more at giving students the opportunity to use BIM tools.

2.1 Topics and objectives
Today, in carrying out research work within the studies leading to Bologna Master’s theses there has been a wide acceptance and commitment demonstrated to BIM by the students, so that there is a widespread recognition that this innovative technology is strongly focused on their future. This section presents some of these studies supervised by the author. The proposals of topics of dissertation are aimed at different areas in Architecture and Engineering.

The proposed studies cover different areas focusing on identifying information at each step and on how to perform data interoperability between the various stages using a BIM model. An introduction to BIM paradigm is planned together with the supervisor:

- The student must make an initial literature search regarding the BIM concept: evolution, applicability, advantages and disadvantages;
- The student learns to handle the basic BIM software most frequently used in design offices and to analyze the degree of interoperability that must be established in the transfer of data between computer applications;
- In order to create adequate BIM models and afterwards to allow the accurate transfer of information between the different design phases the Master’s student must acquire knowledge of the standardized file formats, in particular, COBie, IFC and other open sources;
- The student must use his knowledge of this application in a case study in order to learn how to create a model, and to analyze which information is required;
- The student analyses the degree of interoperability between the various steps for creating an effective BIM model and then must draw conclusions concerning the effectiveness of the model and the difficulties found.

As an expected result of the academic research the students, will inevitably improve their skills in an innovative technology of great relevance to the contemporary IT field applied to buildings.

2.2 BIM applied on building projects
In his recent dissertation “Application of BIM technology to building projects” [7] the author, Paulo Neves, an MSc student, focuses on the differences between what the BIM presents and traditional 2D drawing and 3D modeling in the context of a small construction project.

As a case study, modeling the research project revolves around a small construction project near Lisbon, Portugal. This project forms the basis for the comparison between work flow and procedures when adopting BIM as opposed to traditional 2D CAD drawings or 3D models (3D Studio or
SketchUp). The first phase comprises the modeling of the project in Autodesk Revit Architecture, based upon AutoCAD drawings. BIM relies on precise placement of parametric objects along the auxiliary grids and levels to produce the 3D model (Fig. 1). In Revit the user defines all parameters related to the wall structure and properties (walls were made of concrete or bricks, varying only in their width).

Fig. 1. Bases of the modeling process using Autodesk Revit.

Fig. 2. shows the 3D view of the project all modeled in Revit Architecture. The structure of the building is also apparent, with four different levels (effectively 3 usable floors), with the bottom floor being partially underground. The 3D viewing environment allows the user to turn the whole model in whichever direction is intended and it is also possible to obtain top view of different levels of the project.

The Revit capacities used in the case study (visualization, conceptual energy analysis and estimating) were applied and compared to the traditional 2D/3D CAD workflow. To improve the visualization aspect Google SketchUp was used to produce 3D renderings of the project (Fig. 3.).

Fig. 2. 3D model and top view of different levels of the project.

The energy analysis was conducted on a simpler mass model (Fig. 3.), using a sketch-like interface within Revit, where only the general shape, materials, percentage of glass surface and other properties of the project are defined. Using Autodesk Revit Architecture to produce a bill of quantities is a quick procedure that only depends on a well modeled project in order to achieve great accuracy.

Fig. 3. Revit capacities used - visualization, conceptual energy analysis and estimating.

The discussion of the work focuses on the analysis of the results developed with the three different tools, comparing the BIM processes, workflows and results with results attainable with the traditional CAD approach:

- Modeling in Revit revealed itself to be both intuitive and challenging. The fact that the user places representations of building elements in the model adds to the sense of progress and purpose of the design process, because as the modeling progresses, it resembles the finished building more and more closely. Furthermore, all the visualization, conceptual energy analysis and estimating tools are readily available and are easy to use;

- After producing the model all renderings and other viewing schemes are produced effortlessly, as opposed to the traditional method where the designer produces a 2D drawing followed by a 3D model for visualization purposes only. Moreover, even if the architect feels the need to use dedicated visualization software, such as Autodesk 3D Studio Msx to produce better renderings the 3D BIM model can be easily exported and edited in this purpose-made software producing even higher quality renderings;

- The conceptual energy analysis tool is very helpful in the early stages of design when important choices are taken by the architect and client. This tool uses a simplified mass model, comprising not only the general shape and type of the building, but also general parameters such as location, orientation, HVAC systems, glass percentage and wall structure.
The study case showed that modeling in BIM is very straightforward, reflecting the material nature of building elements that was not present in 2D CAD. The use of information rich objects guarantees a more cohesive design and analysis process where different tools can be used to develop and study the project, all based on a primary model initially developed by the architect. The benefits from this are apparent not only in the design phase but also during construction planning and facilities management. Furthermore, modeling this small project showed that if the different stakeholders are aligned in the use of BIM technologies and behaviors, there are evident benefits to small projects that are often left out of the BIM discussion, given their simplicity.

3 PhD lectures

In addition to work carried out on the Master’s program, the PhD program offered by the Department includes the tutorial module “Advanced Course in Information Systems Aided Projects”, coordinated by the author, this within the field of IT in Construction. The PhD candidate, António Costa [8] developed his report under the title “BIM applied to construction management”, while another student, Hawreen Ahmed [9], has tutorial research work in: “Generating and analyzing a full project based on BIM technology”

3.1 BIM applied to construction management

The construction case studied by Costa aims to contribute to the assessment of the potential of the BIM software for 4D model simulation and its interoperability with planning software, such as Microsoft Project. The result of the work presents itself in the form of an application able to simulate the construction, through 3D models defined for each constructive step, according to the MsProject file, and was created on the basis of the plan established for the work. Costa’s study, then, emerges from this context, with the aim of exploring other solutions in developing 4D simulations, using BIM software, and analyzing their advantages and disadvantages. The methodology to support the implementation considered three main components:

• BIM model generation in Autodesk Revit. The building model considers only the structural part of the building. Additionally, at the end of the process of modeling, an IFC format file was created; this was required for the transfer of information between the Revit software and Navisworks;
• Construction planning established in MsProject. The schedule of construction work treats the whole construction process as two modules, for the purpose of an optimizing construction phasing. The period laid down for the completion of each task was obtained from a rough outline, whereas there are no specific limits on the construction of the building;
• Autodesk Navisworks used to process simulation of construction. BIM model was imported to Navisworks based on the IFC format and the importation of the construction schedule was carried out using the file generated in the MsProject. Later, the links between the model BIM objects and the timeline were established. The simulation was then performed automatically by the Navisworks software.

As the case concerned only construction simulation, the information that was imported to the Navisworks from the model BIM, was essentially geometric (Fig. 4.). The construction schedule, developed using the software MsProject, presents a division of the building into two separate modules (Fig. 4.).

Fig. 4. Perspective of the structural BIM model and the construction schedule.

The connection between model elements and the schedule was made directly in the software Navisworks. Each selected object is associated to the activity included in the timeline. The corresponding Gantt map was created automatically by the system Navisworks, respecting all sequence and dates defined in the planning file (Fig. 5). The principal advantages of the applied methodology are:

• the simulation does not require any programming; the interactivity of the BIM software allows greater flexibility to adapt possible changes in the timeline or in the geometric model;
• the simplicity of the software allows an application more widespread use, contributing to a well-deserved appreciation of the importance of virtual simulation in construction.
The main disadvantages of the applied methodology refer essentially to the lowest potential for future developments, taking into account that the solutions considered feature fewer programming capabilities.

For Costa, this work, developed within a lecture module of the PhD course, did contribute to increase his knowledge and skills on BIM. Currently, and as a consequence of these studies, he is the co-coordinator of a training course: "Building Information Modeling (BIM) in Construction Sector" presented in April 2013 at the Technical University of Lisbon, and is to participate in the organization of the first congress presented in Portugal on BIM, “BIM 1st International Conference” in June 2013, in Oporto [10].

Developing the architectural model includes the use of some parametric elements (Fig. 6): walls, slabs, roofs, ceilings, floor coverings and wall coverings, doors and windows, and specialty items (water equipment and furniture). When defining architectural elements in a BIM model some relationships between components must be established. A door cannot be greater in size than the wall that contains it. If a wall is removed from the model, then the doors and windows it contains are also removed. More complex relationships can also be developed, for example, a rule that each door must have a light switch within a defined distance [3]. This is a sort of functionality, it should be noted, and that is clearly not possible within traditional 2D CAD.

Fig. 5. IFC model and Gantt map automatically generated in Navisworks and animation of the construction process.

3.2 BIM applied on a full project
Another student, Hawreen Ahmed, has a tutorial research in progress. It concerns the use of BIM technology to generate and analyze a full project. Hawreen Ahmed from Iran is a PhD student and who started her studies this current academic year. The evaluation of the tutorial discipline is carried out on the basis of a final report [9]. For that, the student must develop a full project, using BIM software, within the engineering focus: architecture, structures, water supplies and HVAC systems.

Today Revit, available as Revit Architecture, Structure and MEP modules, is the most widely used tool for generating BIMs. It contains libraries of standard components, which can easily be copied and edited to create additional components. Door, window and wall schedules are easily extracted to spreadsheets, databases, and other estimating and scheduling packages.

As a next step, Ahmed will develop a suitable structural model: foundations, columns, beams, trusses and roof systems. Furthermore she will develop a MEP model (mainly with HVAC), templates for estimating and for the project schedule. Schedules could easily be created for other elements, such as walls or floors, showing lengths, areas, or volumes. The student is being exposed to several products but does not have the time, in the curriculum, to fully utilize or deeply understand all programs. However, by developing a simple case fully she will obtain enough skill to easily pick up the programs in the future and use them on a more complex project.

4 External training courses
The Foundation for Continuing Training in Civil Engineering (FUNDEC) was established in January
5 Research project on BIM

This final section describes a research project which has been submitted to the FCT (Foundation for Science and Technology), a national public organization, under the coordination of the author and with the participation of an exterior designer. The proposed research concerns the BIM domain “Maintenance of buildings supported on BIM” to be developed in the period 2013-2015 [11]. The purpose of this research project is to establish a BIM framework focusing on the issues of maintenance and visualization supported on VR technology for new or existing buildings. This research proposal aims to improve the solution of integrating maintenance information and system interfaces using advanced visual performances. The project aims to explore the most recent investigation sub-issues for BIM: models supporting maintenance information and incorporation of visual representation of knowledge.

BIM allows the integration of corporate strategy, management, and IT throughout the project’s entire life cycle. However, the reuse of BIM models in post-construction and post-occupancy phases is still in a very early stage. Fully-integrated and sophisticated BIM implementation may effectively support some projects, but, the overall and practical effectiveness of BIM utilization is difficult to achieve. BIM implies mechanisms for optimization of data and issues for its efficiency. In this context, this project intends to provide guidelines for this optimization. File and data systems will be explored and organized with a focus on BIM-maintenance.

6 Conclusions

BIM is currently being introduced into the construction sector at a very fast pace and tends to be seen as cutting edge technology and processes. However, the academic community acts more conservatively to incorporate new technology and to offer new courses, while recent studies in university reveal that some undergraduate programs are making the jump to incorporate BIM in their curricula. In this context, the education work developed in the Department of Civil Engineering and Architecture, at the Technical University of Lisbon aims to improve the knowledge concerning BIM aimed at the future AEC professionals.

The author as a teacher is committed to implementing this pioneer subject in academic programs motivating students to adopt this new technology. The author has supervised several MSc
theses and tutorial PhD lectures concerning the field of BIM design and believes that in the future other students will be engaged in research developing BIM. Today, in carrying out research work within the studies concerning Bologna Master’s theses, there has been a wide acceptance and commitment demonstrated by the students, so that there is widespread recognition that the innovative BIM technology is a strong focal point for their future. Following this strategy the author has organized short professional courses and workshops, which have been very well accepted within the AEC community, the participants showing interest in the topic presented and identifying solutions and modes of action which in the future will use in their activity, thus helping the spread of this innovative technology in their particular professional areas.

This paper demonstrates ways in which schools can be an important driver of BIM knowledge through the new professionals who will incorporate it in their future AEC activity, and supports the opinion that Universities must, as a matter of urgency, focus on the strategy of using innovative technologies to allow students to acquire new skills in the use of BIM software, and knowledge about the capabilities of BIM, to better prepare them for their future activity in a world that is ever more competitive.

References: