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BUILDING INFORMATION MODELLING (BIM) TAUGHT IN ARCHITECTURE (*Paper*)

Topic: Architecture, Teaching theory

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Abstract:
Building Information Modelling (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 building efficiency. Universities must focus on the strategy of using BIM as an innovative technology to allow the acquisition of new skills by students and prepare them for their future activity in a more competitive world.
The management of all information, in its entirety, concerning the different phases of the life cycle of a building, from architectural design to post-occupancy maintenance, can be supported on a single common technological environment. This concept is the basis of BIM technology. There is now a growing interest in the adoption of this technology within the Architecture, Engineering and Construction (AEC) industry. At present, the professional architecture community is embracing new technology quickly, incorporating new opportunities to streamline the design process and to save time and money, whereas the academic community moves more deliberately and thoughtfully to incorporate new technology and to offer new courses. However, it is inevitable that Architectural 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 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. The text describes how the BIM concept is being introduced in the Department of Civil Engineering and Architecture, at the University of Lisbon. The acceptance of a new approach in the presentation of issues, in particular those related to architectural design, requires awareness, on the teachers' part, of the benefits offered by the use of BIM. The paper first focuses on the current situation in teaching and reflection related to updating education in BIM, and latter presents 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. A final topic refers to recent proposals for of research projects in the BIM field.

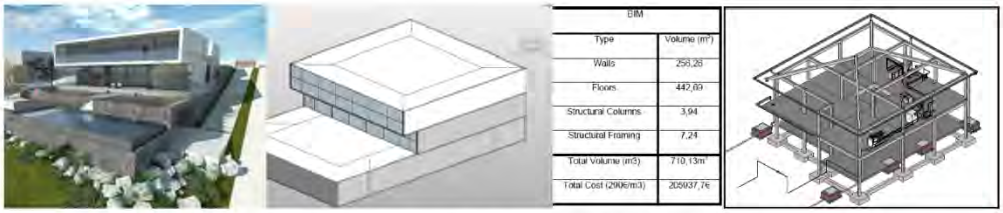

Figure . BIM tool capacities used in visualization, conceptual energy analysis, estimation of material quantities and conflate analyses.

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Building Information Modelling (BIM) taught in Architecture

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Abstract

Building Information Modelling (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 building efficiency. Universities must focus on the strategy of using BIM as an innovative technology to allow the acquisition of new skills by students and prepare them for their future activity in a more competitive world. Based on this perspective, the text presents some educational measures on offer at the Department of Civil Engineering and Architecture of the University of Lisbon. It focuses on the importance of teaching BIM: the involvement of students in research projects, PhD theses and MSc dissertations, and the dissemination of BIM through professional short courses and workshops addressed to the AEC community outside the school. Some of these have already been carried out in the school; others are presently being proposed or currently in progress. It is clear from this paper that school is an important driver for the growth of BIM knowledge and practice through the preparation of new and existing professionals.

– 1. Introduction

There is now a growing interest in the adoption of Building Information Modelling (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]. 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 Architectural 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 University of Lisbon. The methodology of introduction the BIM concept in school is based on proposals to students and professionals of topics to be developed as MSc and PhD research works, short courses and research projects. The next section, focuses on the current situation in teaching and reflection related to updating education in BIM, and later sections 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. The importance of teaching BIM

BIM is one of the most recent acronyms to appear in the world of architecture and construction, the timing of its more formal appearance being difficult to establish. However, neither the concept, nor the nomenclature of BIM, is new. The concept can be dated back nearly thirty years and the nomenclature, around fifteen, with America claiming its origin in 2002 as a means of describing virtual design, construction and facilities management (Race, 2012) [5] while in 2008 the American Institute of Architects (AIA, 2011) [7] issued its first contracts which specifically refer to BIM. The term evolved from the expressions “Building Description System”, “Building Product Models”, and “Product Information Models”, finally merging them all to arrive at “Building Information Modelling”. However, as Kymmell (2008) [8], expresses it, “architects have been using BIM from the very first time information was exchanged in order to get something built”, so BIM should not be seen as something entirely new and different. In fact, as mentioned below, some applications with a small degree of interoperability have been in use since the late 20th century.

Engineering education always strives to follow the interests of the construction industry and currently BIM is a very attractive topic. Not only does BIM show a building at every step of its development and illustrate construction, design and materials in detail but the embedding capacities of BIM make it a dynamic platform that allows multiple groups in different locations to work on projects. Increasingly, the technical information in a BIM concept is rich and highly structured. The students in an Architectural school and the team in a design office must acquire adequate skills to be in a position to make use of this technical information, according to the design phase data the users intend to get from the model.

According to Sabongi [6] “the academic community moves more deliberately and thoughtfully to incorporate new technology and to offer new courses”, a number of undergraduate programs are now incorporating BIM in their curricula. The literature mentioned below illustrates the efforts to introduce this material into higher education:

- Construction Management Faculty at California State University organized a study to examine the effectiveness of BIM, as a construction visualization tool that integrates estimation capacities [9]. The results showed that BIM as a construction tool can improve estimating skills;

- Clevenger et al. [10] discusses the faculty motivation, summarizes student input, outlines academic material development, and presents preliminary student feedback for the strategy of including BIM in the Civil Engineering curriculum. The main objective of the changes was to introduce students to the techniques, and to arm them with basic BIM modelling skills;

- In the conference Building Innovation [11], Arto Kiviniemi, from the University of Salford, said "In 2012, we were the only University (in England) that had a graduate program in BIM. This year, there are five or six";

- Universities play a prominent role in the spread of technological change and, especially in the construction field, by the process of dissemination in training students in BIM base tools. Higher education teachers are supposed to be the key actors in education innovation and in the process of change [12]. Universities, consequently, must focus on the strategy of using BIM as an innovative technology.

– 3. Bologna Master's theses and PhD tutorials

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. 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 modelling disciplines.

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. The proposals of topics of dissertation are aimed at different areas in Architecture and Engineering:

- 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;

- In order to create adequate BIM models and afterwards to allow the accurate transfer of information between the different design phases the student must acquire knowledge of the standardized file formats, in particular, 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 analyse the degree of interoperability needed to create an effective BIM collaborative model.

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.

3.1 BIM applied on building projects

In his recent dissertation “Application of BIM technology to building projects” the author, P. Neves [13], an MSc student, focuses on the differences between what the BIM presents and traditional 2D drawing and 3D modelling in the context of a small construction project.

The focus of the work goes towards the modelling effort (undertaken in Autodesk Revit). The dissertation reflects the differences between traditional 2D/3D CAD drawings generally used and the BIM parametric approach: the modelling procedure is greatly changed, producing a central 3D model which can be used to obtain different data (energy consumption, estimates and visualization for example) without the need to redo the model, with the associated loss of productivity. The results indicate that BIM would be suited to small construction projects, particularly when visualization, estimating and conceptual energy analysis are used. As a conclusion, the research work project confirmed the overall positive trend within the AEC industry regarding BIM adoption and its benefits.

Figure 1 show the 3D view of the project all modelled in Revit Architecture. 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.

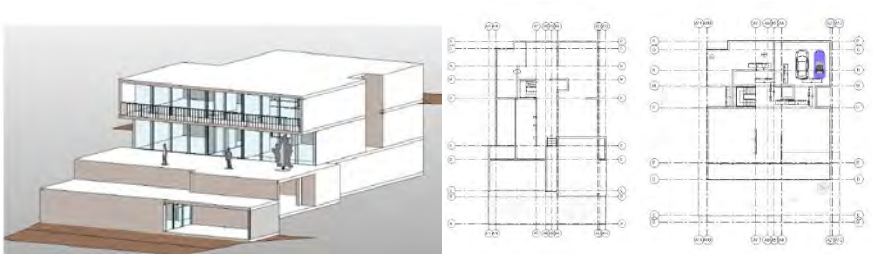

Figure 1. 3D model and plant views of the architectural project.

The energy analysis was conducted on a simpler mass model (Figure 2), 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 modelled project in order to achieve great accuracy.

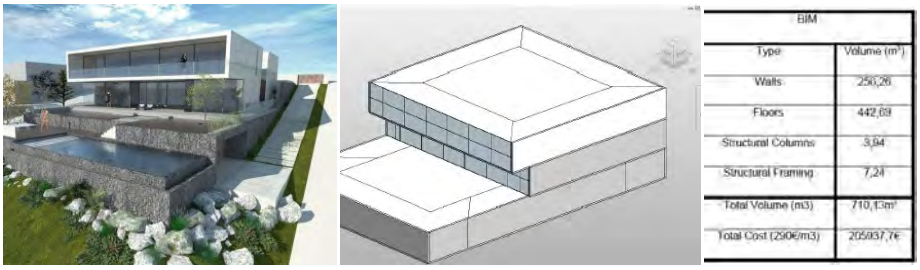

Figure 2. Revit capacities used - visualization, conceptual energy analysis and estimating.

The study case showed that modelling 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. Furthermore, modelling this small project showed that if the different stakeholders are aligned in the use of BIM technologies and behaviours, there are evident benefits to small projects that are often left out of the BIM discussion, given their simplicity.

3.2 Conflits analyses in a BIM based design

The aim of a Master study developed by Berdeja [14] 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. As such, it was case study the development of an architectural, structural and building service (Mechanical, Electrical and Plumbing,

MEP) BIM models and their subsequent conciliation and clash detection. In this work, commercial software such as Revit 2014, Tekla BIMsight and Navisworks Manage were used, the latter two providing features for automatic collision detection. A BIM model concerning architecture, structures and MEP was developed. The BIM technology provides automatic clash detection during the development of the building design. So, using the software of automatic detection of conflicts between elements of the three building components a final solution to the MEP model was established (Figure 3).

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 a building design.

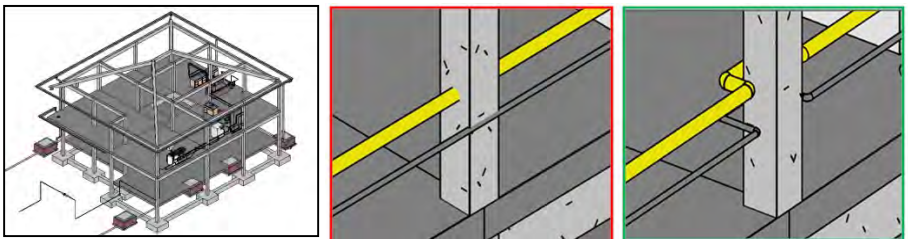

Figure 3. Analyses of clash conflits between structural and MEP components.

3.3 BIM applied to construction management

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, A. Costa [15] developed his report under the title "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. The methodology to support the implementation considered three main components (Figure 4):

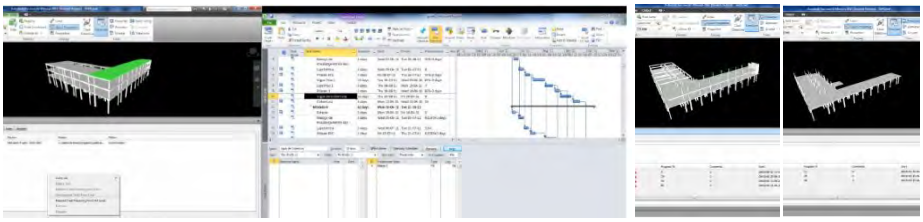

Figure 4. Animation of the construction process using Navisworks.

- BIM model generation in Autodesk Revit and additionally, at the end of the process of modelling, 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; Autodesk Navisworks used to process simulation of construction. BIM model was imported to Navisworks based on the IFC format and the links between the model BIM objects and the timeline were established. The simulation was then performed automatically by the Navisworks software.

The main advantages of the applied methodology refers essentially to the great potential for future developments: 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.

3.4 BIM applied on a Architectural project

The tutorial work of another student, Hawreen Ahmed, concerns the use of BIM technology to generate an architectural project [16]. Today Revit, available as Revit Architecture, 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 (Figure 5).

Figure 5. Architectural BIM model.

When defining architectural elements in a BIM model some relationships between components must be established. Furthermore the students used 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. By developing a simple case fully the student obtained 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) with the aim of improving the skills of people engaged in Civil Engineering in Portugal, promotes, to this end, professional training and courses, studies and services. To achieve these objectives, the foundation counts on the participation of the Department of Civil Engineering and Architecture and its qualified staff to satisfy the needs of the Association. In addition, the operations to be carried out necessarily correspond to the needs felt by the technical and business stakeholders.

Following this strategy of the Department, the author is the coordinator for the professional short courses FUNDEC. The main aim of the courses is to disseminate BIM technology as a means of supporting the management life cycle of the building, particularly directed to the activities of design, construction and maintenance. The first course “Information technologies applied to buildings: BIM and VR technologies” was held in November 2012, and included the presentation of some case studies developed in BIM environments. The notion of the course was well accepted within the AEC community, the interested parties showing interest in the topic presented and identifying solutions and modes of action for future use in their activity.

A new course has been proposed for the present year: “Implementation of BIM Technology in the AEC industry”. This includes an introduction to BIM: concept, state-of-art, applications, benefits and limitations; analysis of interoperability between the various sectors of the AEC industry and presentation of some cases illustrating successful implementation. The course is aimed at various levels and sectors of the AEC industry. This second course focuses more directly on the problem of the implementation of BIM in the AEC sector and specifically on computer science knowledge concerning the BIM paradigm. Particular attention is paid to the MEP model, specifically, in the analyses of conflicts between BIM models. The use of 3D Scanner technology in BIM is also explored

as a technology to capture building shapes for rehabilitation projects. The contents of this second course are list below:

- Introduction to BIM concept: Definition, State-of-art, application, benefits and limitations; Interoperability and standardization
- Computer-based BIM technology
- Limitations of the model BIM interoperability in building management
- BIM as a computer-aided design tool: Generation of architectural, MEP and structural models; Analyses of conflicts between models
- 3D Scanner technology applied in BIM.
- Full BIM model: a study case

– 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 [17]. 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 knowledge related to VR technology and maintenance planning, acquired in previous research projects [18] and educational research will be explored within the context of a BIM strategy. 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 [19]. 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. Besides the effectiveness, an actual investigation sub-issue for BIM is the integration of visual data among different construction sectors [2]. Using visualization expands the usability of data/information/knowledge. With respect to presentation of maintenance information, BIM framework will include visualization of condition assessment data and visualization of 4D model simulating materials evolution of coatings and other building components. The capacity of visualizing and simulating the degradation in 4D model will give a more understandable overview of the life cycle performance and will enable effective use of resources, increasing better communication and supporting long-term planning of maintenance, repair and rehabilitation. Furthermore, visual knowledge representation and viewer interaction, supported on VR technology, are topics to be developed in this project in order to archive important benefits to maintenance. The research work must incorporate VR-based interactive techniques and input devices to perform visual exploration tasks.

– 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.

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