

The Introduction of the BIM Concept in Civil Engineering Curriculum*

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Building Information Modeling (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 Technical 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.

Keywords: education; BIM; concept; curriculum

1. Introduction

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 Building Information Modeling (BIM) technology. There is now a growing interest in the adoption of this 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.

It is evident, as Sabongi [6] says that the standard of non-integrated, stand-alone courses no longer meets the needs of students who will be employed in the construction industry. The new project management tools, such as BIM, are challenging for undergraduate construction education. Students' post-university employment increasingly depends upon their ability to integrate all facets of the curriculum and to comprehend more than the more widespread design-bid-build model of project management. Thus, the basic BIM technology must become one of the essential tools in students' training, in the future, to facilitate their integration in a demanding and competitive work environment. Lecturers and academics must first concentrate on learning how and why usability of new digital tools can improve the design of buildings in order to better offer students, knowledge of diverse technological solutions that are beginning to be disseminated. IT play a significant role in modern information-driven societies, making a comprehensive understanding of digital media a fundamental requisite to success; it is also of importance that young students are today highly motivated to learn innovative digital technologies [7].

The text describes how the BIM concept is being introduced in the Department of Civil Engineering and Architecture, at the Technical University of Lisbon. It has been reported that there is, of course, a great resistance to introducing a new paradigm in the design of the building and its development throughout the different stages of the evolution of a building and, later, of post-construction monitoring of the building. Any curriculum-wide change to a traditional course of study requires acceptance by the entire faculty. Today, this may be an obstacle standing in the way of more widespread use of the new BIM paradigm in construction education [8]. The acceptance of a new approach in the presentation of issues, in particular those related to the structures, construction processes, construction planning, maintenance of buildings, project coordination and management of information concerning the life cycle of a building, requires an awareness, on the teachers' part, of the benefits offered by the use of BIM. To achieve this, 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, 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 contin-

uous 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 [5] while in 2008 the American Institute of Architects (AIA) issued its first contracts which specifically refer to BIM [9]. 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 Modeling" [10]. However, as Kymmell 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.

2.1 Implementation and research direction

BIM is being used ever more frequently in private industry and in U.S. government projects as a method of integrated project delivery [6]. Any BIM-based activity implies collaborative and integrative use by the individual designer, the immediate team in the individual design practice, the wider project team and supply chains, as well as users and maintenance personnel. BIM also covers information creation, collection, updating, archiving collating, coordinating, validating and sharing. Since a BIM model can include 2D graphics, 3D graphics, intelligent objects, parametric and all physical and electronic forms of non-graphic information, it could contain all types of information, from spaces and geometry, to costs, programming, specifications and other information types [11].

To allow that, relationships must be built between data to exploit the full benefit of BIM, and open standard formats must be used to translate data from one proprietary format to another. A digital exchange format COBie UK 2012 has already been prepared in order to provide a minimum level playing field [12]. COBie is, essentially, a spreadsheet data format that contains digital information

about a building in as complete and as useful a form as possible. So, real world construction must get to grips with BIM. Open BIM technologies, such as building SMART International's Industry Foundation Classes (IFCs), have been developed over many years (since 1994 in fact) and exist with the sole aim of enabling interoperability between BIM applications [11]. IFC is a suitable mechanism for the creation of COBie data drops and there are tools already in the market place that generate COBie from IFC, but overall the support for COBie in BIM applications varies and needs improvement. This requires a complete understanding of the practicalities of BIM, and a greater knowledge of the role of IFC and COBie in BIM practice.

Engineering education always strives to follow the interests of the construction industry and currently BIM is a very attractive topic. In the 1990s, teachers began to teach CAD package that worked with parametric building elements as opposed to traditional 2D line drawings [3]. In 2010, BIM made significant leaps forward and is now very much part of many construction professionals' lives. By using the geometry and spatial relationships, quantities and properties of the building elements within a BIM, real efficiencies and improvements in accuracy are being made in the design, construction and maintenance of buildings. 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 Engineering 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.

2.2 Introduction in engineering education

Drafters huddled over drawing tables are an image from the past [6] mainly because, today new structures are being designed by architects and engineers who are well able to use a wide variety of software programs, including BIM which is fast becoming part of the construction sector and, according to Mordue [12], "tends to be seen as cutting edge technology and processes". Even though, 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:

- In order to introduce students of Auburn University, U.S., to basic concepts of BIM, an introductory course in BIM has been integrated in a construction management program [8]. Some prerequisites to BIM and the delivery of fundamental skills on digital visualization, CAD drafting and 3D modeling, were previously introduced briefly, to the students. As a conclusion of the experience, it was found that BIM acts as an integrative force within a construction curriculum and a vehicle for delivering knowledge about building.
- 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 [13]. The results showed that BIM as a construction tool can improve estimating skills and make an impact on the effectiveness of Civil Engineering students in their jobs.
- Clevenger et al. [14] 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 capabilities of a specific modeling program in building design, and to arm them with basic BIM modeling skills.
- The conference Building Innovation 2013 [15], held in Washington, looked at how BIM is being taught to the next generation of building industry professionals [16]. Professors from several different universities shared their educational curriculum approaches and changes introduced in various program disciplines, namely, architecture, engineering, construction, project management, interior design and landscape architecture, facility operations and even communications. Advice arising from the conference was that the partnership between industry and academia and ways to integrate BIM should be improved. Arto Kiviniemi, from the University of Salford, said "Last year (2012), we were the only University (in England) that had a graduate program in BIM. This year, there are five or six";
- Ibrahim [17] states that myriad technologies are promising innovative solutions to problems of coordination and delivering projects on time and budget through integrated project delivery. However, there is limited understanding of how these technologies are actually implemented and there is a need to separate myth from reality. BIM appears to be the emerging leading paradigm but the major identified challenges in using the new technologies are knowledge and training.

More focus on actual BIM implementations in projects, the challenges of integrating multiple technologies across the whole project/asset life-cycle, and closer attention to their use for addressing sustainability issues, are needed. So, teaching BIM in higher education institutions is urgent.

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 [18]. The effective training and teaching of the innovative technologies depends on the full exploitation of the potential of these technologies. Competence, therefore, in the new technologies as a set of knowledge, skills, and attitudes for using BIM tools must be first assimilated by the higher education teacher; Universities, consequently, must focus on the strategy of using BIM as an innovative technology. In fact, as Mordue [12] observes, "BIM has come a long way in a relatively short time". However, there is still a lot to be done even though the academic body and newly trained professionals are beginning to contribute to this field.

3. 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.

3.1 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:

- BIM technology application in the architectural design of buildings;
- 4D construction planning based on BIM technology;
- Coordination of building projects based on BIM technology;
- Analysis of the BIM model implementation in building structure projects;
- Contribution to the implementation of the BIM model in construction project;
- Information management of the life cycle of the model-based BIM building;

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 limitations;
- 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, how to classify and organize the information used and to recognize what data should be added and incorporated into the model in order to support the processes of construction, maintenance or management;
- The student analyses the degree of interoperabil-

ity 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;

- The difficulties encountered regarding the interoperability aspect should constitute a positive contribution to the acceptance and implementation strategies of the BIM concept in the AEC industry.

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.

3.2 BIM applied on building projects

In his recent dissertation “Application of BIM technology in building design” [19] 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. The first part of the work comprises a comprehensive literature review relating to BIM and how this innovative technological approach differs from what is commonly done in Portugal. This part of the text presents a generic initial approach of BIM with relevance to: definition; history and chronology; discipline specific benefits, barriers and implementation strategies; software tools used in structural engineering, interoperability, future and gaps in current knowledge.

Secondly, the focus of the work goes towards the modeling effort (undertaken in Autodesk Revit). The dissertation reflects the differences between traditional 2D/3D CAD drawings generally used and the BIM parametric approach: the modeling 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. As far as the tools are concerned, all of them proved very useful, providing very similar results to those obtainable with the normal approach, using only the 3D model and Revit software as a base. The results also

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.

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).

The proposed exercise to the student consisted in developing the architecture model of a small building, from drawings defined in AutoCAD as a way to train a new BIM-based tool, and explore the new tool in the perspective of realistic visualization, of calculation of energetic characteristics and of obtaining the quantities of materials. Figure 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 BIM paradigm opens new perspectives on how to deal with the life cycle of a building project, in which the whole process develops on the basis of a 3D model and information about the whole project is included in that model.

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

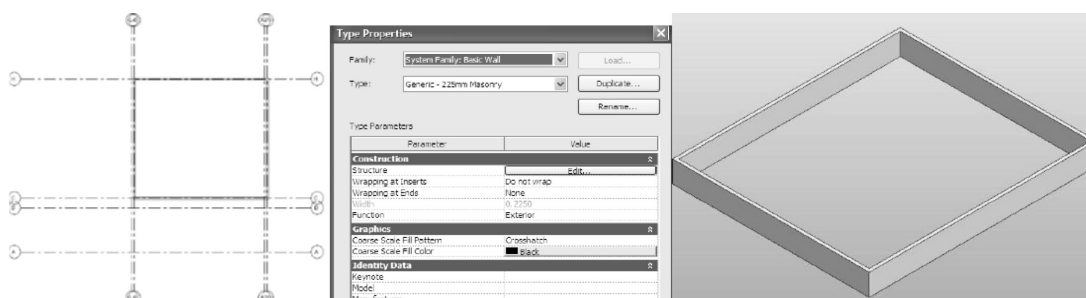


Fig. 1. Bases of the modeling process using Autodesk Revit.

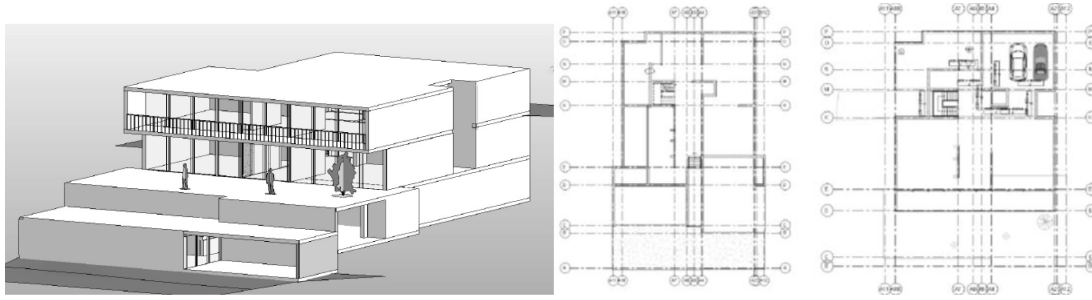


Fig. 2. 3D model and top view of different levels of the project.

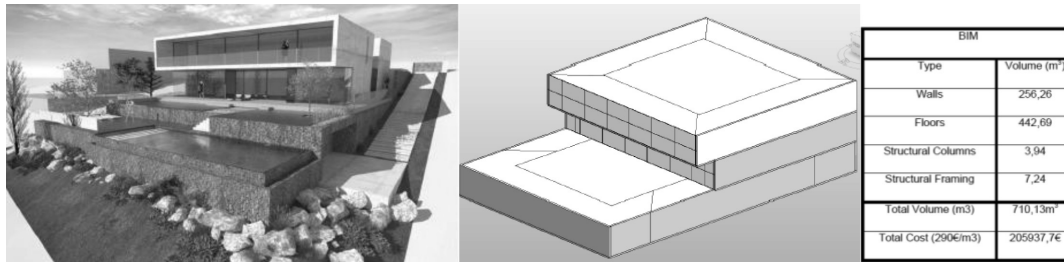


Fig. 3. Revit capacities used—visualization, conceptual energy analysis and estimating.

produce 3D renderings of the project (Fig. 3). 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.

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 Max 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 quantity and cost estimating is a fundamental phase of any construction project, being a responsibility of the general contractor. This estimating procedure is based on the ability to measure the quantity of different materials present in the project. This tool is seen as a primary BIM tool by initial users that fail to understand the full scope of BIM, comprising design (visualization), construction and post-construction benefits (facilities management).

Neves concluded that after modeling the project in Revit and performing different analyses and tasks, there is an apparent difference from traditional CAD drawings, representing a step forward for any design or construction company willing to invest in training and software. 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.

3.3 Dissertations in progress

The Master's dissertations that are currently in development concerning both fields of Structural Engineering and Construction activity are:

- Luis Barreto "Interoperability analysis of BIM technology in the design of buildings" (Structural Engineering). This study focuses on the analysis of several existing technologies in order to be able to compare them with the BIM methodology: a comparative analysis between the various methodologies and the main advantages and limitations found in BIM must be devised. A study case must be created as a basic parametric 3D model, coupled with diverse information (architectural, structural and construction). The relationships between the data of different steps of the model must be analyzed to exploit the full benefit of BIM on building design. Open sources and standard formats must be studied and used with the development of the research work.
- Vitalino Azevedo "BIM model analysis from the perspective of the project of structures" (Structural Engineering). The period of analysis chosen for this research is the structural phase and for this, a case study, still to be developed, is required. This will include an analysis of the data type needed in the implementation of the structural model and how to obtain the required information. Another important aspect is the exploration of methods of exporting information from the BIM model to structural calculation programs, the research focusing on interoperability in great detail.
- Diogo Simes "Maintenance of buildings supported on BIM model: limitations and proposals for improvement" (Construction). The target period of the research proposal is the post-occupation of a building. This study aims to identify the necessary information regarding maintenance activity that can be extracted from the BIM model, and how to use, transform and reuse it. The study should assess the information extracted from the model BIM and recognize the complementary information required in the maintenance activity. The study must be applied in a case study and conclusions must be carried out.

4. 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, Antnio Costa [20] developed a report under the title "BIM applied to construction management", while another student, Hawreen Ahmed [21], has tutorial research work in "Generating and analyzing a full project based on BIM technology".

4.1 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 study case considered by the student consisted in a two-storey building and the related structural solution. The structural model, defined in a BIM-based tool, the Revit Structure, was created based on drawings defined in AutoCAD. The planning of the construction phases used was the same considered in the initial project. This case study evolved from the work developed by Santos [22], which had as its objective the development of a 4D simulation using virtual reality software, EONreality. 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.

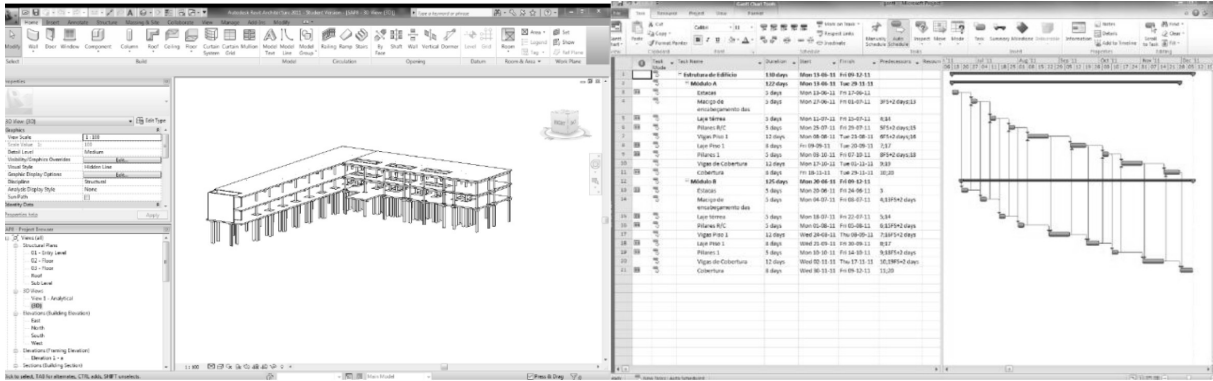


Fig. 4. Perspective of the structural BIM model and the construction schedule.

- 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.

Autodesk Revit, as a structural BIM modeler, offers great advantages since most of the elements are already predefined (for example, slabs and massive pillars, etc.). Any amendment the designer wishes to introduce is much simpler to make in BIM software than on common 3D software such as AutoCAD, since all elements are connected parametrically. In addition, all 2D drawings are also automatically corrected. 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).

Navisworks is used for integrating models from a variety of sources. It features excellent conflict detection and resolution and animation capabilities [8]. To generate the 4D simulation, the IFC model and the timeline were imported to the Navisworks software, and then the necessary link between the different components of the model and the steps of the timeline were established (Fig. 5). 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 Navis-

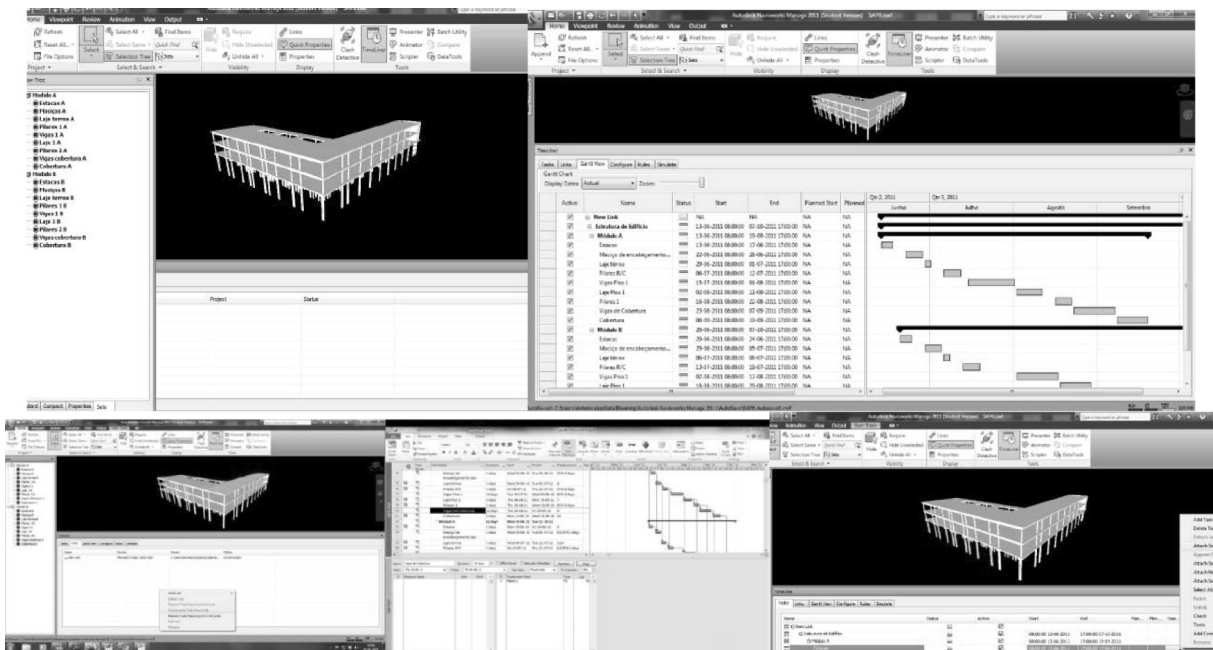


Fig. 5. IFC model and Gantt map automatically generated in Navisworks

works, respecting all sequence and dates defined in the planning file (Fig. 5). The results obtained through the application of the methodology presented made it possible to demonstrate that BIM software supports the creation of the simulation of a construction process (Fig. 6). When compared with the work on 4D simulation developed by Santos [22] the principal advantages of the applied methodology are: (1) the simulation does not require any programming; (2) the interactivity of the BIM software allows greater flexibility to adapt possible changes in the timeline or in the geometric model; (3) 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 refers 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” to be held in April 2013 at the Technical University of Lisbon, and is to participate in the organization of the first congress to be held in Portugal on BIM, “BIM 1st International Conference” in June 2013, in Oporto [23].

4.2 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. In accordance with the established PhD study plan, she must attend the lecture module “Advanced Course in Information Systems Aided Projects” in order to acquire knowledge and skills relating to the use of BIM-base software. The evaluation of the tutorial discipline is carried out on the basis of a final report [21]. For that, the student must develop a full project, using BIM software, within the engineering focus: architecture, structures, water supplies and HVAC systems. The work involves calculations relating to budgets and conflict analysis between architecture and services. The example considered by the student consisted of a small one-storey single-family housing. The student created the architecture model based on sketches. The definition of all the elements of architecture was being elaborated and changed using the BIM-based tool, the Revit Architecture.

There is already a wide range of BIM software available and in recent years there has been a growing availability of new solutions, diverse applications with greater capacity for visualization, simulation and calculation. In Portugal, the most widely used are the software of Autodesk (Revit Architecture, Revit Structure, Revit MEP, Navisworks) and Graphisoft (ArchiCad, ArchiFM, MEP Modeler, Constructor). All of the products owned by Autodesk are offered, free, to students by Autodesk. The hardware system requirements for this BIM software are similar across the packages and the software can be run on commonly available PCs with the addition of a high-end graphics card.

Taylor et al. [8] defends the notion that students must work on a project of challenging scope and complexity in order to more fully understand the extent of developing a BIM model. However, to

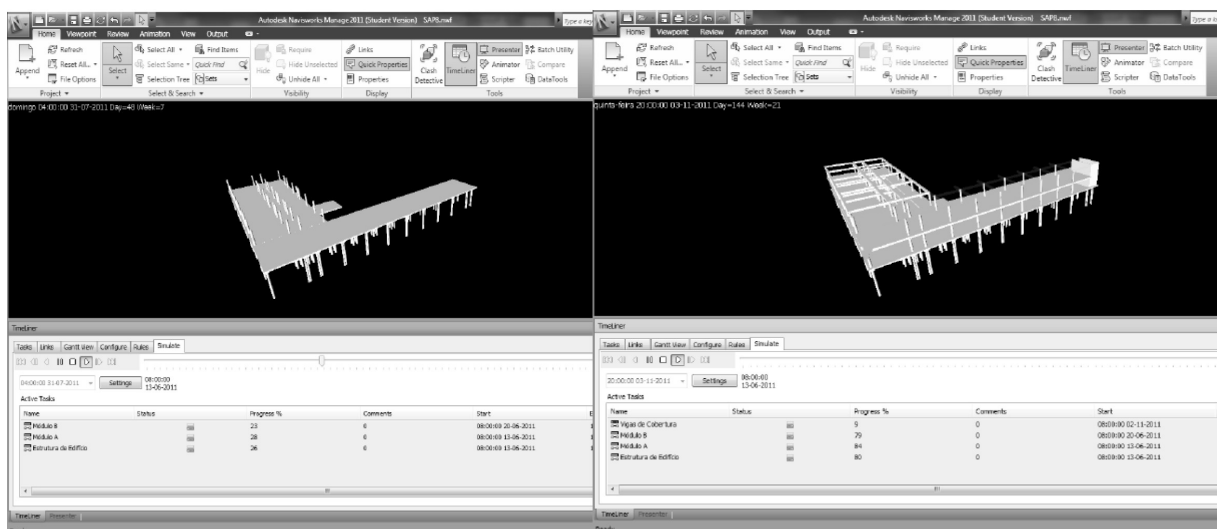


Fig. 6. Animation of the construction process.

cover the multi-steps of a building design, using BIM based tools, in a one semester, it would dictate that only a small sample building could be used. The project case must have a complete architectural plan, site, and MEP drawings. Taking this as a guideline, the student has been creating a BIM model of a typical familiar house; she is, in fact, required to develop a full project using different BIM tools. BIM is a geometric model and is also an estimating and scheduling repository. As future professionals must handle all information of the multi-phased full project, Ahmed must learn not only how to use a model to develop the model as is required in the industry. After completing the research she will be able to use the software available and to fully understand the concepts behind the technology, thus achieving the main aim both for herself and for the field in general.

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. When generating the model, using Revit Architecture, as the class did not lend itself to regular lectures, or studio sessions, the student was required to learn the software on her own without the benefit of formal instruction. She was, therefore, required to use the self-paced tutorial of the software and was able in this way to learn enough about it to create the architectural design.

This illustrates the notion that Revit is fairly easy to manage without any formal instruction allowing the student to develop the ability to create the model and to better understand how to use it.

Developing the architectural model includes the use of some parametric elements (Fig. 7): 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.

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.

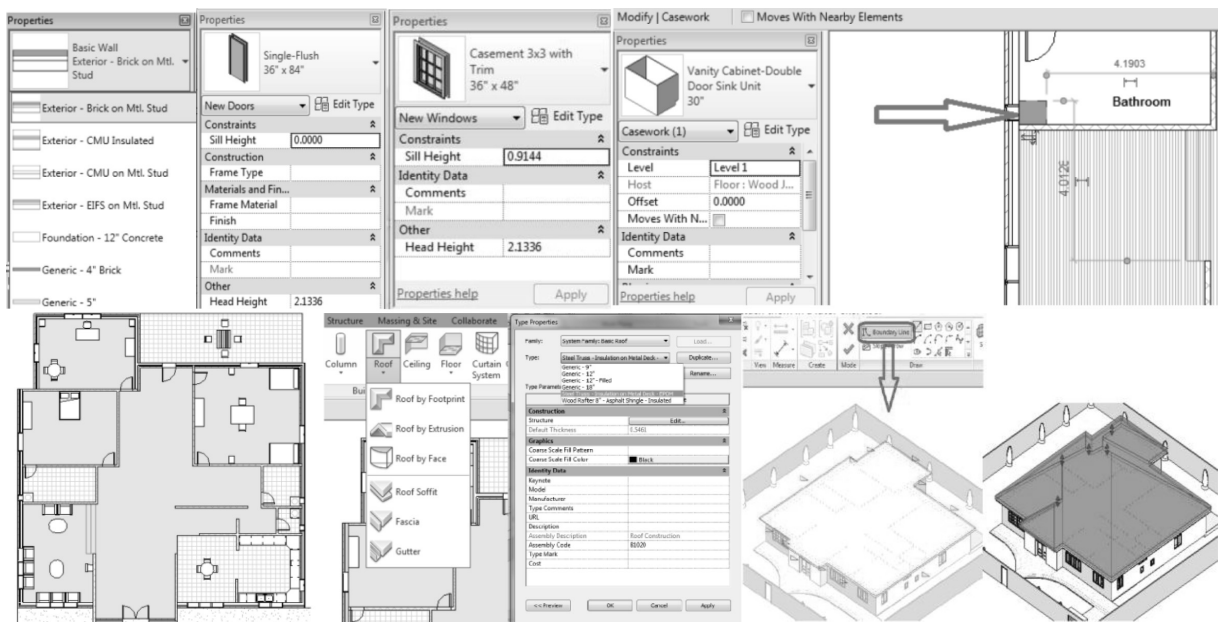


Fig. 7. Architectural model with walls, slabs, roofs, doors and windows, and furniture.

5. External training courses

The Foundation for Continuing Training in Civil Engineering (FUNDEC) was established in January 1995 with the aim of institutionalizing continuing training actions within the framework of civil engineering. It seeks to revitalize those activities in areas considered with priority to meet the needs of each sector of economic activity where Civil Engineering plays an important role. 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 RV technologies’’ was held in November 2012, and included the presentation of some case

studies developed in BIM environments. The BIM concept was used to create the information associated to the life cycle of the buildings, supported by suitable data management. Virtual Reality (VR) Technology is used in the creation of interactive interfaces, supporting technical information visualization and collaboration among participants in construction and maintenance activity. 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. Table 1 shows the schedule of this second course.

Table 1. Program of the second FUNDEC course

May 27, 2013	
08:45–09:00	Registration and collection of documentation
09:00–10:00	Introduction to BIM concept <ul style="list-style-type: none"> • Definition, State-of-art, application, benefits and limitations; • Interoperability and standardization. <i>Prof. Alcnia Zita Sampaio, Technical University of Lisbon, DECivil</i>
10:00–10:45	Computer-based BIM technology <i>Prof. Francisco Regateiro, Technical University of Lisbon, DECivil</i>
10:45–11:00	coffee-break
11:00–12:00	Limitations of the model BIM interoperability in building management. <i>Prof. Paulo Carreira, Technical University of Lisbon, DEImformatics</i>
12:00–12:45	BIM strategy in education. <i>Prof. Antnio Leito, Technical University of Lisbon, DEImformatics</i>
12:45–14:00	lunch
14:00–15:45	BIM as a computer-aided design tool: <ul style="list-style-type: none"> • Generation of architectural model, MEP model and structural model; • Analyses of conflicts between models. <i>Eng. Pedro Pina, Urban360</i>
15:45–16:00	coffee-break
16:00–17:00	3D Scanner technology applied in BIM. <i>Eng. Jos Ramos, 3Dtotal</i>
17:00–18:00	Full BIM model: a study case <i>Diogo Simes and Edgar Berdeja, MSc students, Technical University of Lisbon, DECivil</i>

In May, 2008, a workshop entitled: “Technology BIM-Building Information Model” was also given, with the participation of invited designers who presented some projects coordinated and planned with a BIM. This was attended by a considerable number of participants composed of students of the final years of the civil engineering and architecture courses. In general these kinds of activities, not included in the regular curricular program, are well accepted.

6. 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 [24]. 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 use of knowledge visualization, on the representation of performance-over-time data in 4D (3D + time) models, and the incorporation of interactive capacities to represent the BIM framework will increase the communication and collaboration between partners and then support decision-making in the planning of construction maintenance. The knowledge related to VR technology and maintenance planning, acquired in previous research projects [25] 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 [12]. 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.

7. 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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