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INTRODUCING BIM INTO EDUCATION: OPPORTUNITIES AND CHALLENGES

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Abstract.
Digital transformation is altering the way architecture, engineering and construction (AEC) professionals worked traditionally. BIM (Building Information Modelling) technology is at the centre of this transformation, connecting design, construction, management and operation of buildings. Its advantages versus previous practice are many and benefits owners, designers and contractors. Demand of BIM projects is growing significantly and is expected to increase faster in the next years while the industry improves the standards and available tools are developed further. Education in Civil Engineering must acknowledge these changes and include BIM in the core of its contents to prepare future practitioners.

The introduction of BIM philosophy in education presents advantages not only for future professional practice, but also for current students. This article covers the opportunities of BIM introduction into education: (1) It would help students to improve both hard and soft skills, highly valued by employers. (2) It would attract more students to Civil Engineering studies by changing its image of being an old-fashioned sector. Existing barriers for this introduction related with the current teaching methodology and software use will also be mentioned. Despite the efforts to adapt university courses to introduce BIM, these changes must be encouraged as this investment will pay off in the medium term with better trained professionals which in turn will increase productivity in the AEC sector.

1 INTRODUCTION

Digital transformation is altering the whole economy and changing the way professionals used to work. With certain delay compared to others industries [1], the architecture, engineering and construction (AEC) sector is also embracing these changes. Building Information Modeling (BIM) technology is at the centre of digitization of the AEC sector [2]. The demand of BIM projects is growing significantly and is expected to accelerate in the next years while the industry improves the standards, software tools are developed further and more clients make it mandatory. Education in Civil Engineering must acknowledge these changes to properly prepare future practitioners and include BIM in the core of the academic contents.

Compared to other industries the AEC sector has traditionally been more conservative and changes have been introduced slowly; this has led to relatively low productivity and efficiency levels. The introduction of the BIM technology aims to revolutionize the industry in design, construction and operation. The use of computer-aided tools and data in a comprehensive manner as proposed by BIM presents many advantages compared to the traditional use of software tools, but also requires changes in the way practitioners used to work.

University degrees are sometimes criticized for focusing too much on theory and not much on practice. The introduction of BIM into Civil Engineering studies presents an opportunity to provide a more practice-oriented training, improving both hard and soft skills. Moreover, it can change the perception among young students that the AEC industry is old-fashioned, which frequently stops them considering it as a career path [3]. Although the introduction of BIM into education presents some barriers, most of them are salvable as addressed in this paper. Governmental and academic institutions should promote and facilitate the introduction of the necessary changes given the benefits of the BIM technology. Efforts to adapt university courses to introduce BIM will pay off in the medium term with better trained professionals which in turn will increase productivity in the AEC sector.

2 BIM TECHNOLOGY

2.1 The use of software tools in the AEC industry

The use of software tools in the AEC industry has been growing exponentially during the last decades and today they are an essential part in professional practice. Software tools increase greatly the productivity of practitioners taking advantage of modern computers to undertake automatically repetitive, time-consuming tasks and solve complex problems. The supply of software tools is widespread and covers from drawings production to generation of bills of quantities, from structural analysis to water supply networks design.

The development and application of computer-aided tools is usually limited to solve a certain problem of the project (definition of the physical model, estimation of the cost, design of structural elements, definition of the geometry of supply and sewer pipes…). This is so because projects are usually undertaken by several professionals (the architects, the project managers, the structural engineers, the utility engineers…) which are in charge of specific parts on which they are specialized.

It is obvious that the different parts in which a project can be subdivided are interrelated because, after all, the project is unique (the physical model defined by the architect affects the structural model of the structural engineer; the location of beams and columns restricts placement of supply and sewer pipes…). Traditional software tools do not take advantage of this interrelationship, which not only leads to an increment of the workload (for instance, the architect, the structural engineer and the utility engineer need to define each one a model from scratch), but also makes it more difficult to identify clashes between the different disciplines in the design phase (for instance, intersections between the pipe network and structural elements such as columns and beams).

2.2 What is BIM?

BIM is a process for creating and managing data related with construction projects which covers from design to operation through construction. A BIM model is a digital representation of a construction project. It does not only include the 3D geometry, but also the properties of the different elements forming the project (structural elements, pipes, insulation elements), geographical information, time and cost data, maintenance… To have all this information in the same model presents several advantages versus working with different, independent models. Some of them are mentioned next:

(1) It reduces the workload and, hence, costs associated with the project development. Data shared in the BIM model does not need to be defined twice. For instance, if the architect has created the physical model, the structural engineer does not need to define it again before defining the structural model; this also guarantees that they work with the same geometry.

(2) It reduces the occurrence of conflicts between parts undertaken by different people. Having all relevant data from different disciplines in the same model permits to identify clashes between elements and modify them accordingly in an early stage. This results in substantial cost savings in the construction phase, when modifications of the project are much more expensive.

(3) It promotes collaboration between the different agents working on the project. It is for the best interest of all participants to create a realistic, complete model.

(4) It permits to visualize the project in a comprehensive manner. This feature has clear benefits to better understand the implications of construction and operation of buildings. These advantages will be even greater with further development and refinement of augmented and virtual reality tools.

2.3 Open BIM

Some BIM software tools present constraints related to the compatibility and interoperability with other applications. This can represent a real limitation to practitioners if they are forced to use certain software for compatibility reasons rather than for technical/preference reasons. Open BIM is a complementary proposal to traditional BIM which puts information on the centre of the workflow rather than on the software application. It is an initiative of buildingSMART [4] supported by several leading software vendors, including CYPE.

Open BIM is based on the use of standard, open, public files which permits sharing information regardless of the application used. The most popular file inside this philosophy is the IFC file (Industry Foundation Classes). This technology permits a transparent and open workflow and facilitates the participation of all professionals without imposing constraints on the use of certain software. Moreover, the use of standard formats facilitates subsequent data analysis which will be of great interest in an economy where big data is meant to be revolutionary (if it is not already).

An IFC file with the 3D geometrical model is necessary to start a project in the Open BIM workflow (BIM Project Starter) (**Figure 1**) [5]. This file can be generated with any modeling software for architecture; free applications are available in the market (e.g. IFC Builder by

CYPE). The IFC file is then placed into a directory which is shared with the rest of project participants and where all the information generated by them will be shared. As the workflow is based on a standard, open file (IFC), any software application importing and exporting this format may be used by the participants, giving great flexibility to choose software based on professional/personal preferences. The original IFC file is then completed with additional IFC files generated by the specialized tools and the BIM model is updated consequently.

The Open BIM workflow permits the development of specialized tools without having to tackle the whole problem. This opens unlimited possibilities to developers to work on smaller applications which solve a specific problem in different project fields: structures, HVAC, plumbing, electricity, telecommunication, lighting or other disciplines, and which can then be integrated into the workflow with other tools. The BIM server center managed by CYPE offers an excellent platform for developers to offer their BIM software products to the general public.

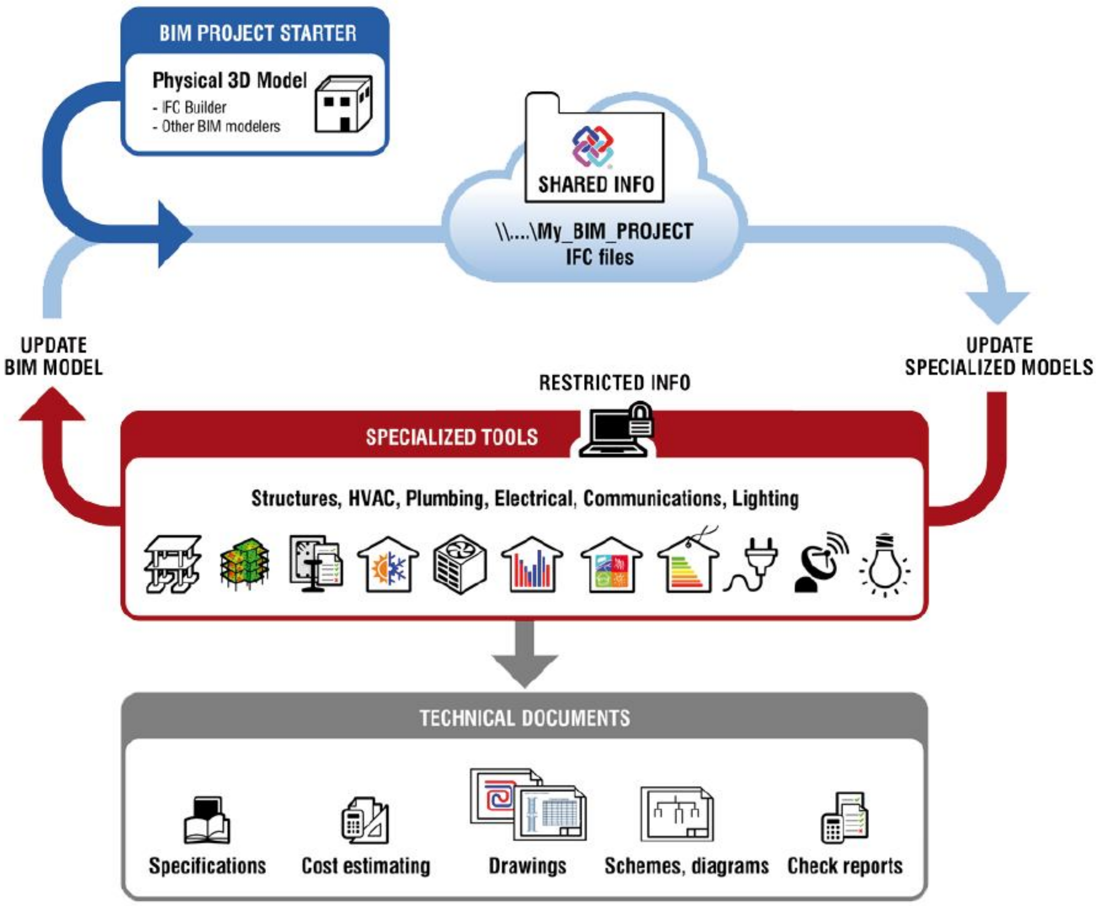

Figure 1. Workflow diagram in Open BIM

3 OPPORTUNITIES

Introducing BIM into education presents many opportunities, not only because it will prepare students better for professional practice, but also because it will result into more attractive education programs in the digital age.

3.1 Professional development of future practitioners

Education must prepare students for the job market by providing them with those capabilities needed and valued in professional practice. Two different skill categories are usually distinguished when evaluating a job candidate: (1) hard skills and (2) soft skills. Hard skills include knowledge and abilities which are acquired through education and training, in general related to a specific field and which are usually quantifiable. Soft skills, also known as "people" skills, are related to the ability of individuals to interact with others and involve emotional intelligence. Traditionally employers used to focus mainly on hard skills (university degrees, courses, certifications, languages, software use…), but in the current workplace soft skills have gained much importance; indeed, it could be stated that today they are as equally important as hard skills. Introduction of BIM into education results in improvements of both hard and soft skills as detailed next.

Regarding hard skills, two important capabilities can be enhanced with the introduction of BIM into education: (1) handling different computer-based tools for the resolution of engineering problems and (2) engineering knowledge by itself. The use of computer-aided software in engineering offices is widespread, highly valued by employers and usually a requirement. Nowadays the number of engineering software applications is so large that it is impossible to be familiar with all of them. However, having learnt some of them facilitates the learning process of other tools. Therefore, those students who arrive to the job market with a good degree of expertise in the use of some engineering software tools, even when these are not specifically the ones required by the employer, have a great advantage versus those who have not learned any tool during their education. Related to the second hard skill, computer-aided tools facilitate teaching engineering concepts thanks to examples of applications and trial-and-error tests that can be undertaken easily. For instance, identification of the influence of different factors in design becomes clearer with computer applications (e.g. study the effect of reinforcement quantity on the column strength).

As mentioned above, Open BIM promotes the development of tools for the solution of specific problems which can then be integrated into the workflow via the IFC standard. This can represent an incentive to students to develop their own tools either individually or in group projects as part of a course. This would not only provide them with a computer-aided tool for the resolution of the problems they need to face, but also will encourage them to understand better the theoretical concepts embedded in the application before programming it. As mentioned earlier, the BIM server center managed by CYPE then provides an excellent platform to offer the developed products to other users, which is always very motivating for engineering students which can see how their work can have an impact in real practice. This was not possible until now as applications needed to be very complete and, hence, clearly out of the scope even for the most advanced students.

Regarding soft skills, BIM process promotes (1) leadership, (2) communication and (3) collaboration: one of the participants must play a manager role and coordinate the work of the rest; working everyone on the same projects requires a good communication between team members to know at which stage each member is and work together on potential clashes identified in the BIM model; and collaboration is critical in order to develop a comprehensive model including all relevant, matching information.

3.2 Motivation of current trainees

The AEC industry is frequently identified as an industry with a low degree of digitization, where no major changes have appeared in the recent decades. For this reasons the AEC industry is frequently seen as an unattractive sector by young students who were born in the digital era. Introduction of BIM into education can change this image.

The idea of creating virtual buildings through the development of BIM models is engaging and more appealing than producing drawings or analysis models whose connection with reality is frequently difficult to establish. In addition, the use of software may make more attractive the learning process in engineering, which is characterized in many cases by complex concepts whose usefulness at first sight is not easy to identify for a student. Therefore, introduction of BIM into academic plans could results in an increment of the interest showed by high students on construction-related careers.

4 CHALLENGES AND BARRIERS

The introduction of BIM into education is not free of difficulties and barriers considering the traditional teaching methodologyand the use of software in academic centers. However, these barriers are salvable as addressed in this section.

4.1 Teaching methodology

Introduction of BIM into education requires bringing in some changes in the current teaching methodology. This affects especially to coordination between different faculties and courses. The scope of university courses is usually limited to a specific field inside the construction industry (courses on reinforced concrete design, water networks design, urban planning…). Currently most courses operate independently; the only relationship may be in many cases that more advanced courses require background knowledge from previous courses. Therefore, with the current system a student needs to wait almost till her final year to have a clear picture of what a construction project entails.

The introduction of BIM into education requires enhancing coordination and collaboration between different courses because it would not be reasonable to work on a BIM project if the student cannot see how the different parts of project fit with each other. The development of BIM group projects by students from different courses and even from different degrees would be of great interest. This would not only permit students to fully grasp the essentials of construction projects and BIM, but also to foster collaboration with other students outside the classroom, promoting the development of soft skills.

Introduction of BIM into university courses would be at the expense of other areas. Currently, much importance is given to theory in engineering studies and little space is given to practice. Importance of engineering theory is doubtless to educate future professionals, but this sometimes results in disregarding the importance of practice. In this sense, introduction of BIM into Civil Engineering studies would help to even out theory and practice.

It should also be noticed that sometimes there is some mismatch between academia and professional practice. In some cases university changes occur with a certain delay compared to industry trends. This is a consequence of conservative practice, but also of the difficulties of introducing modifications into the university system, especially when these involve structural changes. The establishment of testing groups or programs could be a good initial approach to check the suitability of the new modifications and also to attract more students looking for the latest trends.

4.2 Software use

The introduction of software tools into educations is not always as straightforward as one may think. First, the software to be used needs to be decided. Decisive factors include appropriateness for students, applicability in professional practice and cost of license fees. In addition, for BIM applications compatibility with other tools should be considered. In this sense applications inside the Open BIM workflow are very appealing as data interchange through IFC files guarantees the interoperability with other applications. Regarding the cost associated with licenses fees, some software vendors offer free versions for students and universities. CYPE not only offers free student versions, but also many of its professional versions to both students and practitioners.

Second, and related with the interoperability between different programs, it is of importance to guarantee that students will be able to work as realistically as possible when compared with professional practice. This is of special interest for projects involving different disciplines (especially for courses in collaboration with other degrees or faculties as proposed in section 4.1…). Sharing models and information between students is critical in these cases. For this purpose the online platform BIM server center managed by CYPE offers many opportunities: file interchange takes place in real time; students can work on the same project at the same time; interaction and clashes are identified automatically.

Third, software tools are sometimes denoted as black boxes, which can be a disadvantage for teaching purposes as it is of importance that students grasp all the implications of the models used. Despite this, some software tools as those developed by CYPE generate not only final results, but also provide intermediate results and lists of checking which facilitate to follow all the process without hiding relevant information. Moreover, and as mentioned in section 2, the Open BIM workflow facilitates the development of own tools which are not black boxes anymore.

5 CONCLUSIONS

BIM is transforming and gaining much importance in the AEC industry. Attracted by its benefits, more clients are requiring the development of BIM models for their projects. Indeed, BIM is mandatory by many public sector organizations and, hence, affecting directly to the civil engineering industry. Professionals who are trained or have experience in this new technology have a tremendous competitive advantage versus those who do not.

Civil Engineering studies must recognize BIM importance and adapt courses to introduce this technology. Opportunities and challenges have been addressed in this document. Benefits for the AEC and the society will pay off the investment needed in introducing these changes.

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