INTEGRATING BIM EDUCATION INTO CIVIL ENGINEERING CURRICULUM

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Received: 15 March 2017 / Accepted: 7 June 2017 / Published: July 2017

Abstract: *It is widely accepted that BIM (Building Information Modeling) is going to become an international standard in AEC (Architecture, Engineering, and Construction) industry in the near future. To cope with this, the coming civil engineers should be prepared to have appropriate BIM knowledge at University. Through literature review, the author draws out an overview of BIM technology and current status of its implementation, and the approaches to bring BIM education into the curriculum under expertise point of view. As a result, a list of subjects in Construction Engineering Curriculum at Hong Duc University, which should be tied with BIM knowledge, are proposed and some recommendations also are given.*

Keywords: *Building information modeling (BIM), construction and engineering education.*

1. Introduction

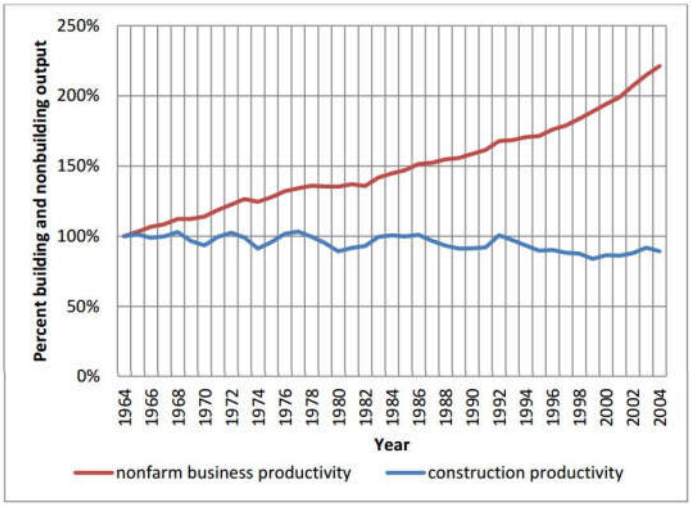

Figure 1. *Labor Productivity index for the US Construction industry and all non-farm industries*

(Source: Teicholz, Paul. "Labor Productivity Declines in the Construction Industry: Causes and Remedies." AECbytes Viewpoint. Issue 4. April 14, 2004)

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To date, the construction industry is still taking huge proportion resources of every economy, especially in developing country. Therefore, enhancing the resources consumption in AEC projects is of remarkable value for each nation. In US construction market, in 2004 the Construction Industry Institute estimated that 57% of money spent on construction is nonvalue-added, which is waste [1]. Furthermore, there has been no productivity gain in the construction industry over the last 40 years (1964-2004). In fact, there has been a steady decline, whereas all other non-farming industries rose over 200% in productivity (Figure 1).

In addition, it is recognized that the bid process and resultant change orders have become the bane of many construction projects. Hence, the traditional style Design-Bid-Build should be replaced by IDP (Integrated Delivery Project). Additionally, construction projects are becoming more complex and huge with longer time. To deal with that issue, there have been many attempts to solve problems. One of the most promising solutions is BIM technology.

Despites the fact that benefits of BIM have been well known, the implementation level of this concept is various among countries. Besides the developed countries with highly level BIM used, most of developing countries are in early stages of BIM implementation. One of the cause for this pattern is the lack of engineers with adequate BIM training and education, which is costly for small or medium construction company in a developing country. To fill this gap, the universities which are having AEC programs should take responsibility to provide appropriate BIM knowledge for their students, who are going to become the civil engineers. In respect to that concern, this paper aims to provide an initial point of view about the role of BIM with civil engineering students generally and then propose some adoption to bring BIM into the construction engineering curriculum at Hong Duc University particularly.

2. BIM - An overview and current status

The purpose of this section is to provide a better understanding of BIM concept and its benefits for next generation of civil engineers. Additionally, through literature to define BIM characteristics, which will be used to propose the approaches for BIM teaching in the following section.

2.1. BIM technology in brief

The concept of BIM has existed since the 1970s [2]. However, thanks to the development of IT technology (especially 3D-Graphic aid design software), BIM has become a popular concept since early the 2000s, then it has already been mandatory practical level in many developed countries by now, and is going to be an international standard for AEC industry in near future.

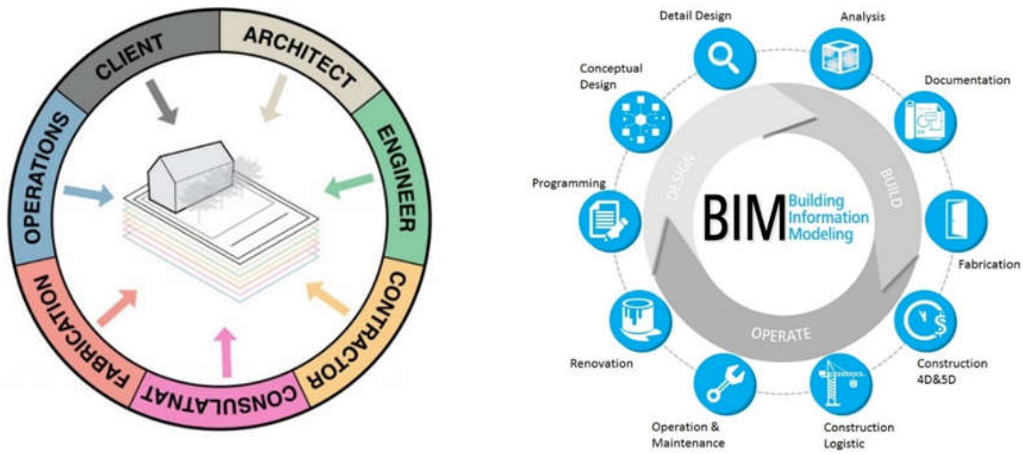
There are many definitions of BIM concept. In which, two of those are frequently mentioned. At first, Chuck Eastman et al. (2011) states that “BIM is a fundamentally different way of creating, using, and sharing building lifecycle data”. It emphasizes that the object of BIM technology is all relevant data of projects. The second common definition comes from

National Building Information Modeling Standard (NBIMS) of the United States, in which BIM is categorized in three ways:

BIM as a product; which is the building being presented through an intelligent digital model.

BIM as a collaborative process; which is consistent relationships between standardized parametric data, business drivers and all relevant participants.

BIM as a facility; which presents the procedure, workflow, and information exchange during the lifecycle of the project.



a) b)

Figure 2. *(a) BIM as a facility; (b) BIM as a collaborative process*

Figure 2 presents two main characteristics of BIM. Figure 2a presents a point of view about BIM models, where all stakeholders participate in the project through a unique BIM model (in their own vision). In another point of view, Figure 2b, the BIM software can be used as a facility for all phase and activities in a construction project: Design-Build-Operate. The main difference between conventional software and BIM is that instead of creating "a product" for every stage (or for some similar tasks), BIM model is unique in every project (or at least with its perspective) will be built up through the wholelife cycle of project and the final model contains all relevant information, which was created in its lifecycle, about the project. In brief, BIM concept is not a new professional knowledge of construction engineering or technology, whereas it is an IT-based model (product, process) to deliver construction project efficiently.

According to Salman [3], the key benefit of a building information model is its accurate geometrical representation of the parts of a building in an integrated data environment. Other related benefits are as follows:

Faster and more effective processes: Information is more easily shared and can be value-added and reused.

Better design: Building proposals can be rigorously analyzed, simulations performed quickly, and performance benchmarked, enabling improved and innovative solutions.

Controlled whole-life costs and environmental data: Environmental performance is more predictable, and lifecycle costs are better understood.

Better production quality: Documentation output is flexible and high automation.

Automated assembly: Digital product data can be exploited in downstream processes and used for manufacturing and assembly of structural systems.

Better customer service: Proposals are better understood through accurate visualization.

Lifecycle data: Requirements, design, construction, and operational information can be used in facilities management.

In brief, BIM concept is an approach to create and manage all data of construction projects in a unique model, which is changing both the efficiency and delivery method of construction project performance. Along with the development of IT technology, BIM concept has already been a technology in construction industry.

2.2. BIM implementation level and current status

As a developing technology, many researchers, organizations and nations have given the guidance and standards for evaluating the implementation of BIM. The section introduces two popular diagrams which describe the level of BIM implementation in construction projects.

Firstly, the level of how far has BIM technology been applied is evaluated through concept "BIM Dimension". It starts with 3D BIM, which provides a3D geometric model. 4D-BIM model includes the scheduling function (time). 5D BIM with the cost to be modeled. 6D-BIM model allows performing energy analysis and 7D-BIM supports facility management. By now the BIM software, which provides BIM services for 4D and 5D dimensions, is using popularly. The latest version of Revit (2017) allows user to perform energy analysis automatically on the model (Figure 3).

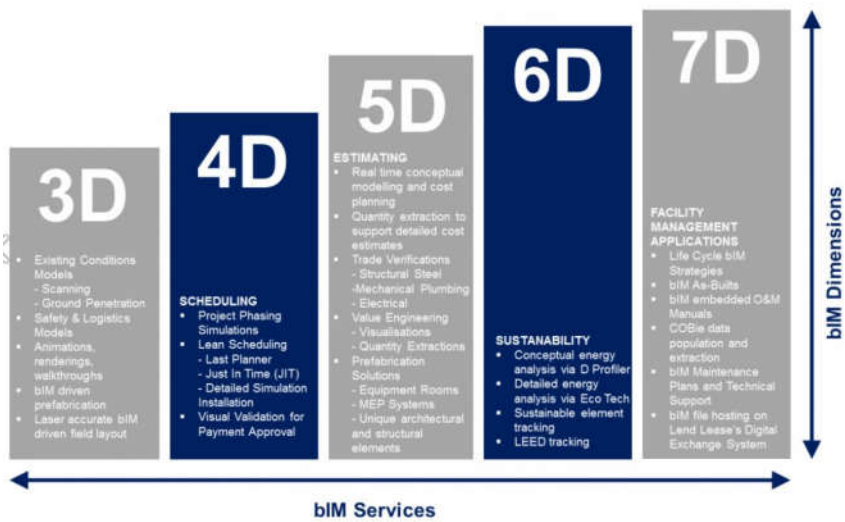


Figure 3. *BIM functionality in implementation level*

The second approach to assess BIM implementation is considering the level of collaboration and technological sophistication throughout the building process. Eve S. Lin et al. (2015) [4] proposes a diagram of BIM maturity level, which was also adapted from some previous diagrams as show in Figure 4. As can be seen clearly, the trend of development and implementation of BIM is able to perform automatically more services (D-Dimension) with more comprehensive of format (Tools-Platform-Environment).

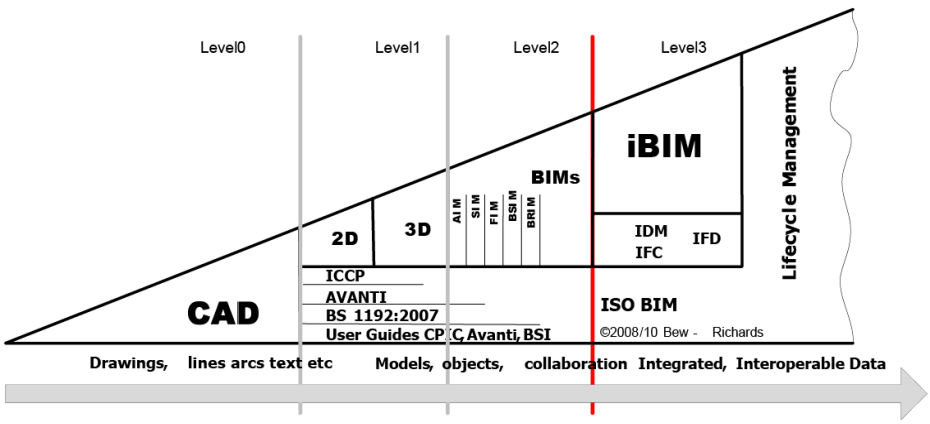


Figure 4. *Illustration of BIM maturity levels*

To address BIM implementation status, plenty of surveys have been conducted. McGraw-Hill Construction(2014) has made an extensive global survey for tracking evolution and implementation of BIM since 2007 to that time. The report reveals that whilst BIM implementation has been led by countries such as US, UK, Germany, Canada, France, and it also has been adopted in countries such as Australia, Brazil, Japan, North Korea and New Zealand. "BIM usage is accelerating powerfully, driven by major private and government owners who want to institutionalize its benefits of faster, more certain project delivery and more reliable quantity and cost" [5]. They also have found significant change over that period and impressive implementation increases over the past few years in particular. For example, in North America, BIM adoption by contractors escalated from 28% in 2007 to 71% in 2012. On the higher implementation level, many national governments have already made BIM as a mandatory requirement such as US, UK, Norway, Denmark, Finland, Netherlands, South Korea, Singapore, Hong Kong [6].

The picture of implementation BIM in two biggest economies of developing countries, China and India, also are promising. In China, a BIM Union was formed in 2013 and "Unified Standard for BIM Application" has been completed and issued for comment [7]. McGraw-Hill Construction(2014) found that BIM implementation in India is in the early stages. However, with the fact that construction market is predicted grown to $620 billion by 2020, many international companies are moving into this market and BIM will come along with them [7].

In Vietnam, there was a research which was conducted by Construction Economics Institute- Construction Ministry of Vietnam to plan for adoption BIM process in the particular

condition of Vietnam. Based on that, BIM will be deployed from 2018 with the certain huge projects [8]. In the meantime, there are several projects, which have mentioned as BIM project with international consultants such as Tran Thi Ly Bridge (Da Nang), Rao Bridge - Binh Bridge (Hai Phong) [9].

In conclusion, BIM has been an actual standard in the construction industry to ensure the success of projects. Using BIM is going to play avital role to enhance competitive capacity of every construction company in globalization era. In consequence, the coming civil engineers should master of BIM technology as such a pillar for their career and the universities have to take their responsibility to bring BIM into the curriculum.

3. The approaches to integrate BIM into civil engineering education

Since BIM has widely been accepted that it should be avital part of civil engineering education, many academic programs are struggling to meet industry and student expectations. BIM education, according to [10], is a process of learning the sum conceptual and practical knowledge relating to BIM technologies, workflows and protocols. Underlying BIM educations are many technical (e.g. data management), procedural (e.g. team collaboration) and regulatory topics (e.g. risk management)". With respect to the given point of view, BIM could be taught in two frameworks: BIM concept is provided throughout related professional subjects or BIM is provided as an individual course. The detail of both ways will be discussed in the following section.

3.2. Teaching BIM as a part of existing subjects

With this approach, the specific BIM course will not be created. Instead of that, BIM content and tools are taught throughout of conventional subjects in the curricula. Obviously, it is understandable when the lecturers bring the up-to-date concept and technology in their lectures. Hence, there have been plenty of attempts in this direction [12,11,13,14]. This list is still growing because, as of today, AEC programs exist that have yet to embark on the BIM journey [15]. Once the important of using BIM tools and concept in the traditional course is emphasized as: "*Since the basics of BIM are about using technology to more effectively collaborate and hand off data sets to alternate use groups, how can that be taught without the integration of multiple educational silos."* [16].

The question comes up with this approach is to define the related areas and subject which should be encouraged to tie up with BIM. In a survey of the implementation of building information modeling (BIM) into existing architecture and construction curriculum in Construction and Architecture schools of United States, Maya M. Joannides (2011) [17] has defined 9 related professional knowledge areas which introduce BIM in their content: Civil, Design, Electrical, Estimating, Mechanical, Project Management, Scheduling, Structural, Technology. The survey reveals the percentage of the class format (lab, lecture, or both) of

courses implementing BIM in the undergraduate curriculum (Figure 5). And it can be seen clearly that the combination of both theory (lectures) and practice (lab) is preferable choices.

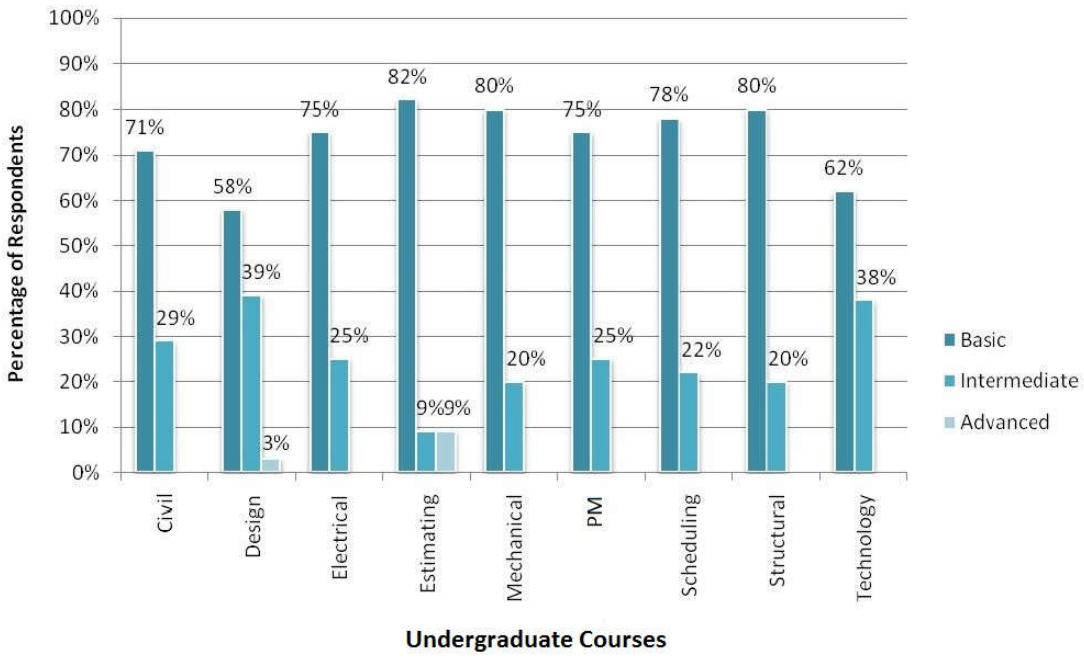


Figure 5. *Class format of Undergraduate Courses Implementing BIM*

Additionally, Willem (2008) [18] stated that "The use of BIM in education can serve to help in design, fabrication, or management related training". It means BIM tools can use to produce *production models (architecture, structural, site plan)* and also *process models (scheduling, cost estimation, planning)*. Based on the above suggestion, the author proposes a list of subjects which could use BIM as effective tools to help students not only achieving professional knowledge but also gain BIM concept/ technology in the Curriculum of Civil Engineering program at Engineering & Technology Department - Hong Duc university as described in Table 1.

Table 1. *List of suggested subjects in civil engineering programs should use BIM as teaching tools in Hong Duc university (Adapted from the official curriculum - version 12.2016)*

Nr	Name of exist subjects	Pts	Type of BIM models	
			Product model	Process model
1	Technical Drawing and Visualization	4	x	
2	Descriptive Geometry - Technical drawing	4	x	
3	Applied Informatics for Structural Analysis	2	x	
4	Reinforced Concrete Structure	3	x	

5	Steel Structure	2	x	
6	Civil Engineering Drawing	2	x	
7	Soil and Stone Engineering	2	x	x
8	Design of Reinforced Rock-Brick Structure	2	x	
9	Concrete Construction Engineering	2	x	x
10	Advanced Steel Structure Design	2	x	
11	Construction Project Management	2	x	x
12	Construction Safety	2	x	
13	Construction Planning and Organization	3	x	x
14	Cost Estimating	2	x	
15	Building Architecture	4	x	
16	Reinforced Concrete Bridge Design	4	x	
17	Steel Bridge Design	4	x	
18	Road Design	4	x	
19	Highway Design	4	x	
20	Bridge Construction Technology	4		x
21	Road Construction Technology	4		x
22	High-rise Building Design	4	x	
23	Steel Building Design	4	x	
24	High-rise building technology	4		x
25	Fabricated Engineering	4	x	x
26	Engineering Practice	4	x	x
27	Graduation Thesis	8	x	x

To perform this approach, the lecturers and supporting facilities play an important role. It is obvious that the structure and the number of subjects in the curricula will not change, the difference is that the lecturers will use appropriate BIM concepts, software to provide the current status of BIM application for their lectures. However, lack of experienced educators is a challenge for adopting BIM in AEC education [19]. Therefore, the university has to provide enough needed facilities (Computers, software, books, etc.) for learning BIM and encourage their lecturers to be acquainted with BIM technology.

As discussed above, the approach to integrate BIM knowledge into existed courses in the curriculum could be most applicable at the first phase of implementing BIM into existing curriculum. By introducing BIM along with professional education, it will help new generation of civil engineers start their career with better quality in international construction companies.

3.2. Teaching BIM as a single subject

In this approach, a single BIM course is developed with specific goals of BIM skills and knowledge. In purpose of developing a course "BIM in Construction Management", Ahn et. al. (2013) listed 9 BIM-Related Courses offered by University Construction Programs in the United States. The purpose of courses can be categorized in 2 areas as follows:

Covers visualization, 3D clash detection, fabrication automation, digital site layout, 4D modeling, as-built model generation, and digital information management using BIM.

Introduces a new way of thinking about deliverable documents and the collaborative framework that a parametrically virtual model can provide.

To gain scientific fundamental for developing a content of BIM course, an intensive survey has been made with construction companies and experts [20]. The important areas of BIM-related tasks in participating construction companies and BIM knowledge and skills required for civil engineering students are described in Table 2.

Table 2. *BIM tasks in construction company and BIM knowledge and skills required*

BIM - Related tasks in a construction company	**BIM knowledge and skills required for civil engineering students**
1. Spatial trade coordination- MEP coordination 2. Visualization 3.Communication 4. BIM in field management 5. Marketing 6. Site logistics 7. Constructability 8. Shop drawing and materials procurement 9. Scheduling and sequence planning 10. Safety-related applications 11. Facility management 12. Integrated project delivery system 13. Laser scanning 14. Simulation of operation - Dynamic animation 15. Model-based estimating 16. Energy simulation	1. General introduction and knowledge of BIM 2. Areas of implementation in the construction process, including visualization, communication,MEP coordination, and so on 3. Relationship between general contractor/ construction management and other stakeholders 5. BIM implementation plan 6. Software compatibility 7. BIM software skills 8. BIM and sustainability integration 9. BIM and integrated project delivery 10. BIM for property and facility management

It is clear that making a new BIM course requires cooperation at a higher level (between Faculty and University). The resources (trained people, IT facilities) and time which are needed for establishing this course are also a barrier for the universities. Because of that reason, this approach should be applied after the previously mentioned approach has been used. However, since it is completed technology and is playing a more and more important role in the practice of construction industry, the future civil engineers should be acquainted

deeply with theoretical knowledge of BIM concept/ technology. Therefore, BIM courses should be a vital part of undergraduate civil engineering as soon as possible.

4. Conclusion

By drawing out an overview of BIM technology, its current status, and future, the paper emphasizes the need to bring BIM into Civil engineering education to help the students have a good preparation for their career. The paper also proposed two approaches to integrate BIM into the curriculum: teaching BIM as a part of existing courses and create a new BIM course in the curriculum. Considering all aspects, those two ways should be established respectively, in such a way that both of two approaches will be performed simultaneously.

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