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Enabling Building Information Modeling (BIM) Practices in the Canadian Construction Industry: A case for an academic program

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Abstract

In today's construction industry, we have been seeing a growing number of complex and high quality construction projects all around the world using BIM (Building Information Modeling) technologies. In order to get the most benefit out of BIM, there is a dire need for efficient standards and robust educational programs and courses to train skilled professionals to support the implementation of BIM in the construction industry.

BIM enables team collaboration, assisting project managers to more reliably communicate project's intent to all stakeholders in a timely fashion. It promotes accuracy and process optimization, saves time, and reduces waste. It is therefore important for industry and academic institutions to work collaboratively in order to understand the level and skillset required for effective implementation of BIM practices in the industry.

Based on a preliminary environmental scan, there is a huge gap between industry BIM needs and available training/educational programs to facilitate effective implementation of BIM tools in the province of Alberta, Canada. Education in the AECO (Architecture, Engineering, Construction, and Operations) field needs to fill the gaps in BIM training for industry to remain current, responsive and relevant. Although an increasing number of educational institutions offering architecture, engineering and construction programs have started to offer BIM related courses, there is no comprehensive curriculum developed by local academia to address the BIM related training needs of the construction industry in Alberta. Research and case studies advocate that industry stakeholders can use BIM technologies to save time and cost, while improving building quality. Integrating BIM collaboratively among stakeholders will also boost competitiveness and productivity in the building industry.

The paper aims to review the current state of BIM training programs in Alberta and recommend a framework of a training program that provides industry professionals with the fundamental skills and knowledge of principles, terminologies, tools, and techniques related to BIM practices. The study suggests that a BIM certificate will help training our professionals better to address the needs of BIM practices in the construction industry. There is a need for a certificate program that provides the required skillset to produce career ready professionals to enable BIM practices in the construction industry. The study findings would be of interest to BIM experts, construction professionals, and faculty involved with BIM education.

Introduction

Building Information Modeling (BIM) is commonly defined as the creation of a model to support the exchange of various types of information to multiple users involved in the design, delivery, and operation of a building through a data rich, object-oriented, intelligent and parametric digital representation of that facility [1]. BIM is the process of using a building information model, or virtual building model, to support activities that take place throughout the life of a building. The model used during the process contains different types of information to support those activities [2].

BIM optimizes team collaboration, enabling project managers to more reliably communicate project's intent to all stakeholders. It is therefore important for industry and academic institutions to work in partnership to understand the level and skillset required for implementation of BIM in the industry.

BIM has grown in popularity and use over the past decade. The advantages to using BIM throughout the design phase of a project and on the construction site have been researched and have proven to be beneficial. The growing trend, especially in larger companies, is that most members of a construction team will access a virtual building model in some fashion during the course of a project. With the growth of BIM use in construction, it is important for colleges and universities - with a construction, building, architecture or related degree - to properly expose their students to BIM related technologies and practices in order to prepare them for the workforce [2].

Only a few of the stakeholders involved in the construction industry actually operate BIM solutions at the building "process" level [3]. BIM is ultimately a tool to facilitate the underlying knowledge structures in the AECO field [3], the complicated relationships between participants in a construction project, and the engineering information flows [4]. A general "BIM Literacy" of all project stakeholders is fundamental for a full implementation of the technology. BIM is defined as a skill rather than a tool, and should be taught as a strategy in communicating engineering information, instead of the operation of any particular tool or application software [5]. BIM use has grown from merely a design-supporting technology into almost a necessity for delivering major construction projects. In a 2012 survey, 74% of contractors reported using BIM in some form, with 55% using BIM on at least 60% of their projects [6].

Building Information Modeling (BIM)

The rising interest in BIM can be seen in conjunction with new project management frameworks, such as Integrated Project Delivery (IPD), which increases the need for closer collaboration and more effective communication [7]. When people collaborate on a project, communicating specific characteristics of that project amongst the different parties involved requires documentation of these characteristics [8]. Traditionally, this documentation was done on a paper or document basis. BIM takes the traditional paper-based tools of construction projects, puts them on a virtual environment, and allows a level of efficiency, communication and collaboration that exceeds those of traditional construction processes [8].

Succar [3] introduces a BIM framework as a research and delivery foundation that maps domain dynamics and allows AECO stakeholders to understand underlying knowledge structures and negotiate BIM implementation requirements. This framework claims to facilitate the relation between BIM concepts and allow its semantic representation through a variety of mediums, including the generation of modules, templates and tools needed to the implementation and teaching of BIM, therefore benefitting both industry and academia [3].

There are many stakeholders involved in the construction industry that are impacted by the increasing adoption of BIM as the industry standard technology. These stakeholders are domain players grouped in the fields of technology, process, and policy. Players in the technology field are involved in the production of software, hardware, equipment, and networking systems. Players in the process field include all people involved in the ownership, delivery and operations of buildings or structures, like architects, engineers, facility owners, contractors, and facility managers. In the policy field, players play preparatory, regulatory, or contractual roles in the design, construction and operations processes. Those players are insurance companies, research centres, educational institutions, and regulatory bodies [3].

Engineering students sometimes do not fully understand the complicated relationships between participants in a construction project, or which are suitable communication techniques and efficient collaboration skills in a full-scale engineering project [4]. Knowledge of engineering information flows, reflecting how physical, technical, managerial, social, and economic information is exchanged between teams, and how collaboration conflicts can be avoided when there are formal regulations to manage them, are seen as important components in BIM education.

Sacks and Barak [9] mention that the civil engineering department of the Technion Institute, Israel, conceptualizes BIM as a skill rather than a tool. In their programs, it is taught not as a tool or in connection to any particular tool or application software, but as a key element in communicating engineering information. The curriculum of this course includes engineering graphics, BIM concepts, engineering drawings, and BIM training. Students with prior CAD (Computer-Aided Drafting) experience found it harder to understand BIM than the ones who never used CAD. Knowledge of the previous paradigm appears to have guided their expectations about the toll’s functionality [9].

“BIM literacy” of project stakeholders is fundamental to the adoption of BIM. Lack of BIM literacy, or a strong knowledge of what the BIM paradigm is beyond the software operation, is currently an impediment for its further adoption and integration [5]. Only in-depth knowledge of what is involved in BIM implementation, leading to realistic expectations of the deliverables from all players involved in the AECO industry, can eventually promote the necessary engagement of all fields to tap into the full potential of this emerging technology.

Succar [3] identifies three maturity stages of BIM adoption that need to be implemented gradually and consecutively within organizations: object-based modelling, model-based collaboration, and network-based integration. In object-based modelling, a 3D parametric software tool is deployed, but to create single-disciplinary models without much collaboration between disciplines. The deliverables in this stage are still 2D documentation, some 3D visualization and basic data exports, such as schedules and quantities. In the model-based collaboration stage, players in different disciplines collaborate around a single model, some contributing 3D geometry while others interface with the model through time analysis and cost estimating software. Finally, on the network-based integration stage, boundaries between roles, disciplines, and project lifecycle phases are removed, and interdisciplinary nD models allow for full integration of all aspects of building design, construction, and operation. This stage can only be reached with a full maturity of all technologies, processes, and policies involved in the construction industry, and will ultimately allow for an Integrated Project Delivery (IPD). IPD is defined as an "approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction" [3].

Jung and Joo [10] mention four phases of BIM advancement, as identified by Taylor and Bernstein [11]: visualization, coordination, analysis, and supply chain integration. A report revealed that, out of 300 BIM practitioners in 2008, the most often used analyses were: (1) quantity take-off – 57%; (2) scheduling – 45%; (3) estimating – 44%; (4) energy analysis – 38%; (5) project management – 35%; (6) structural analysis – 32%; (7) LEED/green analysis – 32%; (8) storm water analyses – 19%; (9) facility management – 18%; and (10) vehicle turning analysis – 15% [12].

Howard and Bjork [13] identify a few obstacles for the full adoption of BIM by the industry. The lack of standards accepted throughout the industry is considered a major obstacle. Property owners also still haven't developed the conviction that they still are not getting full value from the industry. BIM is normally cautiously tested in trial projects without committing to full integration. There is little commercial drive to apply BIM solutions. Finally, the lack of knowledgeable professionals is also cited [13]. As more graduates of construction programs and commercial managers are familiar with the BIM advantages, more pressure is created inside the firms to put it in general use.

Goldberg [14] defends that there is confusion as to who owns, distributes, and takes legal responsibility for building data shared by many consultants and contractors.

Cerovsek [5] writes that “the goal of model-sharing is to enable stakeholders and/or tools to use a “BIM Model” outside of its native modelling environment”. A BIM Schema is a framework for a BIM communication model that allows inter-operability between heterogeneous tools through a standard format. A BIM Schema should: (a) include all information about buildings; (b) cover all information needs by all stakeholders in all phases; (c) be non-redundant; be software-independent; and (d) be format-independent [5].

BIM has a potential use in all stages of the project life-cycle: it can be used by the owner to understand project needs, by the design team to analyze, design and develop the project, by the contractor to manage the construction of the project, and by the facility manager during operation and decommissioning phases [15]. Looking to the future leads to speculation that BIM will eventually lead to a virtual project design and construction approach, with a project being completely simulated before being undertaken for real [16]. Countering the potential benefits of BIM to a construction project is a challenge that needs to be faced if effective multi-disciplinary collaborative team working, supported by the optimal use of BIM, is to be achieved. Other considerations are the changing roles of key parties, such as clients, architects, contractors, sub-contractors and suppliers, the new contractual relationships and the re-engineered collaborative processes [17].

One key role likely to be affected by the introduction of BIM is that of the project manager. The impact of an enhanced use of technology on the day-to-day activities of the project manager and the ultimate impact this has on the outputs and outcome of the project are still not clear [18]. For supporting and encouraging the BIM practices in industry, it is vital for academic institutions to train professionals with required competencies. Academic institutions are the backbone for enabling BIM practices in industry.

BIM training in Alberta

When it comes to BIM adoption in Alberta, it is noticed that the bigger architectural firms are leading the way, but primarily operating in isolation, and therefore stuck on Succar’s [3] object-based modelling maturity phase. Consultants in structural engineering and building systems appear to be reluctant in adopting the new technology. Here this paper identifies the current state of BIM training provision in Alberta. BIM training is offered as stand-alone courses by technology training providers, but with focus on software operation and program features and tools. The Northern Alberta Institute of Technology (NAIT)’s Architectural Technology program appears to be the only provision with an established post-secondary curriculum covering BIM operation in 3 of the 4 program semesters, but still lacks inter-disciplinary integration. BIM training provisions in Alberta are listed on Table 1.

INSTITUTION/ORGANIZATION	COURSES OFFERED	CITY
Edmonton Construction Association	BIM 101 - Introduction to BIM BIM 201 - Introduction to Revit Architecture BIM 201 - Introduction to Navisworks BIM 201 - Introduction to Revit MEP BIM 201 - Introduction to Revit Structure	Edmonton
University of Calgary (Architecture)	Faculty of Environmental Design - Bachelor of Arts Undergraduate Program Faculty of Arts - Bachelor of Arts Undergraduate Program Faculty of Environmental Design - Master of Architecture Faculty of Environmental Design - Doctorate of Philosophy	Calgary
NAIT (Architecture)	Architectural Technology	Edmonton
SAIT (Architecture)	Architectural Technology	Calgary
University of Alberta (Engineering)	Faculty of Engineering	Edmonton
University of Calgary (Engineering)	Schulich School of Engineering	Calgary
Grant MacEwan University	Bachelor of Science in Engineering Transfer	Edmonton
NAIT (Engineering)	Construction Engineering Technology (BIM) Engineering Design and Drafting Technology (BIM)	Edmonton
SAIT (Engineering)	Architectural Technology Civil Engineering Technology Engineering Design and Drafting Technology	Calgary
Grande Prairie Regional College	Power Engineering – Certification Program	Grande Prairie
Keyano College	Bachelor of Science in Engineering	Fort McMurray
Lethbridge Community College	Civil Engineering Technology Engineering Design and Drafting Technology	Lethbridge
Mount Royal University	Mathematics, Physics and Engineering	Calgary

Table 1 – BIM training provisions in Alberta, Canada [19].

A Case for a Certificate program in BIM

For supporting and enabling BIM practices in industry, it is vital for academic institutions to train professionals with required competencies. Academic institutions are the backbone for supporting BIM practices in industry. As indicated earlier, there are very few programs with focus on BIM and that indicates that there is presently a huge gap between BIM training provision and industry needs. This need for BIM professionals demands that the academic institutions train students in an interdisciplinary and applied educational environment.

A polytechnic institution offers a range of technology programs [20]. The variety of technology programs presents a wealth of expertise and a knowledge base that are characteristics of a polytechnic institution [21]. Arain [20] advocates that, due to the multi-disciplinary character of BIM, educational institutions with expertise in the various field related to BIM are in the best position to lead training the required competencies. BIM is a multidisciplinary domain, requiring expert knowledge in the many related aspects of the technology. The multidisciplinary nature of BIM training makes it a natural fit for a polytechnic institution where all expertise could be brought together to train professionals with BIM expertise for industry.

A polytechnic institution attracts a diverse group of life-long learners through a practical, hands-on, and outcomes-based approach to education [20]. For training professionals in the BIM domain with the appropriate skillset that the industry needs, an institution has to be a hub of the technical and soft-skills that are required.

As an emerging academic discipline, BIM is an area where industry needs skilled professionals at both provincial and national levels; and the needs are expected to grow in the future. The context for development of a certificate program in BIM is set by the strong ties that usually exist between a polytechnic institution and the construction industry. Polytechnic institution usually relies on their industry advisory committees to help determine the competencies required by the industry [20].

The proposed certificate program in BIM will be an industry-focused program in Alberta. Its development will involve extensive research, analysis of comparable local and global programs, identification of program outcomes, and comparison of program outcomes with employability skills, curriculum development, and internal and external review processes [22]. Eventually the certificate program will be applied, hands-on, and address the core competencies identified by the industry.

The proposed program will be technologically enriched; laptop delivery program constructed around the unifying framework of program outcomes/competencies. Program competencies will be the defining feature of the proposed certificate program. In a polytechnic institution, program competencies are defined by industry focus groups consisting of industry and academia experts from various related disciplines [22]. The industry focus groups' involvement will be vital for defining the program competencies, and validating course-level outcomes that would support the program outcomes.

In a polytechnic environment where the focus remains on hands-on and applied education, students from various related disciplines would be able to collaborate on the proposed interdisciplinary BIM certificate program, and participate and learn on joint projects. Students will learn the core BIM competencies through numerous projects and case studies from local and global industries.

Conclusion

Given the current technological and industrial developments, conventional methods in construction are no longer capable of meeting the demands of delivering efficient projects. BIM is increasingly becoming a standard of practice in the construction project management domain because of its multi-dimension usability. BIM helps construction professionals stay competitive in an increasingly complex business climate by giving them the ability to better predict the outcome of a building before it is built. Using BIM helps architects and designers create more sustainable and accurate designs with fewer errors and less waste, and to achieve higher profits and more satisfied clients. BIM also optimizes team collaboration, enabling project managers to more clearly and reliably communicate project intent to all project stakeholders.

BIM is an interdisciplinary domain that involves all the fields related to the built environment. There is a growing need for construction professionals with the BIM proficiency that is crucial for enabling BIM practices in the industry. Academic institutions have the responsibility to address this emerging need of an industry that is vital for the national economy.

The paper presents the current state of BIM training programs and recommends a framework of a training program that provide industry professionals with the fundamental skills and knowledge of principles, terminologies, tools, and techniques related to BIM practices. This forms the basis for a proposed BIM certificate program for training professionals to address emerging needs of the industry in the building information modeling domain.

The study suggests that a BIM certificate will help training our professionals to better address the needs for BIM practices in the construction industry. There is a dire need for a certificate program that provides the required skillset to produce career ready professionals for enabling BIM practices in the construction industry. The study findings would be of interest to BIM experts, construction professionals, and faculty involved with BIM education.

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