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BIM UPDATE 2013: A MIXED REVIEW APPROACH FROM ACADEMIA AND INDUSTRY

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Abstract

The newly emerging field of advanced information and communication system (ICT) has popularized the use of building information modelling (BIM) in the architectural, engineering, construction, and operations (AECO) sectors. However, mixed perspectives and misunderstanding are very common towards BIM's agenda and philosophy due to a total change in paradigm of practice and its quick growth in the sectors. This paper aims to render a comprehensive review through a mixed review approach on BIM from the literature up to first of January, 2013 as well as actual industrial observations and experience in BIM projects. The scope focuses on the development and implementation of the past and current state of BIM, and subsequently, inferences are drawn and discussed for the future of BIM based on the developed conceptual framework. Eventually, the paper reveals new implications of BIM for the way forward and updates the existing literature of the overview on BIM.

Keywords: BIM, mixed review, development, implementation, past, present, future, conceptual framework.

BIM Update 2013: A Mixed Review Approach from Academia and Industry

The increased demand and interest of using building information modelling (BIM) is a global trend in architectural, engineering, construction, and operations (AECO) sectors, which is contributed by the enhancement and development for technical and non-technical aspects of BIM. The technical aspects comprise the emergence of user-friendly software, tools, libraries, and high performance computers (Laakso and Kiviniemi, 2012); while the non-technical aspects consist of the continued research and development as well as actual implementation of BIM in the industry. The research into BIM is continuing and has received tremendous attentions from researchers all over the world. For instance, a hundred thirty BIM related articles were published in year 2003, and subsequently, it had rapidly increased to approximately seven hundred articles a year in 2012 as illustrated in Figure 1.

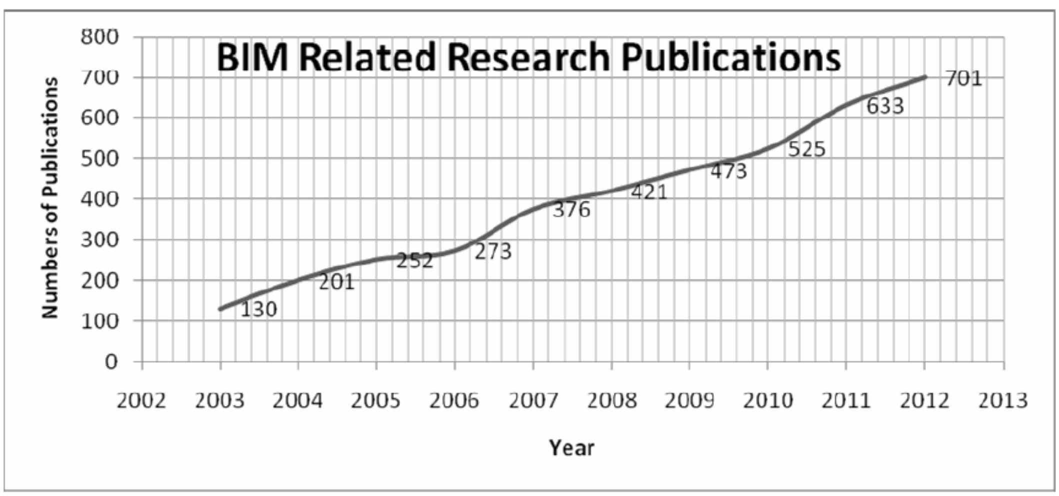

Figure 1. Result of 'BIM' articles in Scopus database (data collected until 1st January of 2013).

Nevertheless, the traditional procurement system remains as the most popular method preferred by project stakeholders. This is mainly due to the reluctance to change and conservative attitudes in the construction industry. According to Cheung et al. (2012), the fragmented practices and adversarial relationships shall be transformed using the collaborative and team-spirit driven platform, namely, BIM. However, one of the critical barriers is different perceptions and misunderstanding towards BIM's actual agenda and philosophy (Gu and London, 2010; Barlish and Sullivan, 2012). Hence, this paper aims to render a comprehensive review on BIM by reviewing the past, present, and the way forward for BIM. The review was authored and contributed by a mixed approach from the perspectives of academia and industry. The literature search and use in the paper have integrated with the experience of the industrial author. This improves the value and accuracy of the data or findings regarding the practical application of BIM, particularly for beginners or intermediate users who would like to venture into the new paradigm of BIM.

Besides, this review paper updates the previous research on the three stages of BIM development (Succar, 2009; Khosrowshahi and Arayici, 2012), where additional and new BIM implications were highlighted for AECO sectors in the developed framework.

The Philosophy and its Past

During the initial computer and information technology (IT) boomed, the construction industry went through a massive paradigm shift as the use of personal computers were widely available. This in turn gave people a new tool to work with, which was resulted in developing many different types of softwares to improve efficiency in all kinds of tasks. To the construction industry, traditional methods of designing and drawing were replaced with computed aided design (CAD), where computers were used to design instead. It has greatly increased productivity and efficiency and also paved the way for more sophisticated, complex, and grand designs as ambitious architects and engineers strive to outdo one another.

However, developers requested more than just using CAD for 2D or 3D designs. The initial philosophy of BIM started as it evolved from CAD in 1987, where instead of having only the design of the building, developers requested additional dimensions and data, such as costs, quantities, time, environmental data and etc. to the basic designs (Grilo and Goncalves, 2010; Nejat et al., 2012). The philosophy of adding these additional dimensions would give the designers a greater insight of not only what their designs would be looked like, but also how their design would function and meet the specific requirements and needs in the industry.

Therefore, BIM has been described as a modelling tool where different dimensions, information, and data can be added into it as deem fit. With all these information come together, many different parties are required to work together and make these information and data available in forming the model. This brings us to the next philosophy of BIM, which is to encourage greater collaboration and communication among different parties in the construction project, may it be within the construction industry or among different industries, where the conventional approach has been relied on numerous exchange of 2D drawings and documents in fostering the collaboration among the project stakeholders (Singh et al., 2011). The interoperability is the key for its effective implementation and collaboration for BIM projects (Cerovsek, 2011). It encourages interaction in terms of communication, coordination, cooperation, collaboration, and channel (Grilo and Goncalves, 2010). These five types of interaction support the philosophy of BIM as BIM is an interoperable technology, where many parties must work together for it to reach its full potential and value.

Currently, there is a clear definition of BIM provided by the national building information modelling standard (NBIMS), which is "building information modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition”.

The Present and its Applications

Even though BIM has been developed and discussed since the 1980s, the adoption level of BIM around the world has generally been slow (Gu and London, 2010; Sattineni and Bradford, 2011). It is mainly caused by the lack of well-trained individuals in the field (Nejat et al., 2012). Nevertheless, it is also generally accepted that BIM is increasingly popular and being adopted (Christenson, 2009). Currently, the following are common applications of BIM in the construction industry, which are derived from literature, BIM case studies and personal experience.

Clash Detections

Buildings and structures consist of many different elements and systems, which are designed by different parties and with a high potential for conflicts among the different systems. This is especially true for mechanical, electrical, and plumbing (MEP) systems. With the high potential for conflicts, the number of conflicts could accumulate into the hundreds or even thousands for large projects and would cost the client badly.

The ability of detecting conflicts is a massive advantage of BIM, which is able to identify the inconsistencies among the designs or elements that produced by the designers. The potential conflicts that may arise can be avoided. Then, it saves the costs for rectifying these potential conflicts (Reid, 2011). With the ability to detect conflicts earlier, it will also result in a decreased number of requests for information and change orders (Madsen, 2008). This detection indirectly would avoid cost for reworks and improve overall productivity of the project.

The clash detections could be carried out in several stages before actual construction. The identified clashes would be increased from the design stage until the documentation stage. According to the case study as reported by Azhar (2011), the model was updated and more than 590 clashes were detected at the construction documents stage, which was approximately saved $800,000 (USD).

Apart from that, currently, there are even more ways to detect and manage conflicts particularly on the construction stage. A mechanism was developed to detect conflicts in construction management by applying BIM and 4D technology (Zhang and Hu, 2011). With their mechanism, a fourth dimension and information was added to the model. This fourth dimension will be information, such as daily reports, progress comparisons, milestones, priorities, and resources involved with the project. With these information, not only will they be able to detect conflicts in the design but also management conflicts that may happen during construction, for example, collisions in the site layout. The mechanism would provide two types of warning system for the parties involved, such as (a) to show the conflicts in the current state of the project and (b) to predict possible future conflicts with the current data. These warning systems provide the management a chance to make the necessary adjustments to avoid the conflicts.

Constructability Assessment and Sequencing

The next current application of BIM is for constructability assessment and sequencing. As described by Madsen (2008), BIM can produce a virtual representation of the physical facility, which enables qualitative and quantitative analyses to be performed. These analyses help to determine issues, such as the number of columns available for the support, the loads ability of structural designs, and so on. Furthermore, Zhang and Hu (2011) also stated that a BIM project with 4D construction simulation can provide structural simulation of the design, which can be adopted by the designers to determine the constructability of the building.

Therefore, a worldwide-accepted standard is necessary to capture and share all relevant data in a BIM model (Nawari, 2012). The BIM generated model shall be linked with industry foundation classes (IFC) modules to enhance its interoperability. The 4D model can be generated as building construction data, such as resources needed, time schedule, and costs are linked with the designed model. This model can then be used to simulate a virtual construction of the design. Furthermore, by linking the model with constructability factors, such as resource availability, site impacts, weather effect and etc., a constructability score can be deduced to determine the constructability of the design (Hijazi et al., 2009).

On the other hand, this area has extended to more comprehensive level of analysis nowadays. An attempt in integrating critical path planning approach and BIM data of construction models was successfully protoyped by Chavada et al. (2012), where it could provide a real time management and visualization of activity execution workspace, i.e., processes of generation and allocation of workspaces; the detection of conflicts between workspaces; the detection of congestion in workspaces, and the resolution of conflicts between workspaces. It applied '1 to n' (one activity linked to multiple workspaces) and 'n to 1' (multiple activities linked to one workspace) to checks the temporal conflicts regarding schedule conflict process and spatial conflicts regarding workspace conflict process. Subsequently, the resolutions of the conflicts were mainly based on the use of the remaining float or the change of the workspace requirements.

Overall, this ability helps the designers and management personnel in making the necessary changes needed to ensure construction of the project, which can be executed smoothly. Ultimately, it could lead to a significant improvement in terms of productivity, efficiency, and safety at the project site.

Cost Estimating

When BIM first introduced and used, one of the first applications of BIM was developed for cost estimating. In a BIM project in Netherlands, one of the main ambitions in using BIM is for cost estimation for the construction of the University Medical Centre St. Radboud (Sebastian, 2011). Currently, the cost estimating process goes through two stages in most BIM models.

The first stage extracts the quantities or quantity take-off from the model. Since BIM enables an accurate 3D model of designs, the estimators can use the model easily in extracting the required quantities of an element. This ability to quickly extract quantities is one of the initial and important benefits of using BIM for cost estimation (Hannon, 2007).

The second stage extends to the pricing for the quantities of the element when the model has connected to databases. The databases contain time/schedule information as well as unit rates or prices of quantities to assist the estimator in pricing (Hannon, 2007). Subsequently, the price and extracted quantities of building materials and elements could be used as sources of information for procurement of materials during the construction stage (McCuen, 2008).

In a recent development, Cheung et al. (2012) have developed a multi level cost estimation tool for BIM at the early stage of the design. The tool is able to determine measurements and quantities and also able to cost estimate through the BIM database with the required data. It also could update the estimated cost simultaneously as the design develops. In summary, this is the trend of cost estimation in BIM, which is able to extract all the geometric data from the BIM model and provide real time cost estimate for the project stakeholders.

Facilities Management

The next application of BIM focuses on facilities management. A BIM generates a model with all the information of the building, such as the records on systems, products, finishes and fixtures of the building. These information can be used by the facility or building manager in managing and maintaining the facilities (Madsen, 2008). For example, the information of a water heater can be obtained, such as warranty details, model number, and date of installation, which will make it easier to maintain the item.

A critical part of facilities management is asset management. This aspect of facilities management can be carried out through the application of BIM. This is done through a BIM with information on all the components in the model. Information on each of these components can be analysed, such as maintenance records, deterioration rates, costs etc.. Accurate deterioration models can then be generated to show when the components have to be replaced or repaired and the cost for every action can also be calculated (Marzouk and Aty, 2012). It is able to enhance overall comprehensiveness and to provide more accurate records on facilities management.

Furthermore, sustainability and energy management are recognized as a critical global issue nowadays, and BIM can also be used to help in to solve these problems. For instance, building performance analysis tools were applied with BIM models to gather information on building thermal comfort and energy consumption (Li, 2010). Subsequently, this information can be used to make the necessary adjustments for sustainable and energy efficient purposes.

The potential for BIM for facilities management is great and still under development. For example, BIM was adopted to optimise the management of the facilities of a hospital project through the registration of medical equipment, fixed and flexible furniture, product and output specifications, and operational data (Sebastian, 2011).

The Way Forward

Academic Perspective

Even though BIM has proven to be very effective and beneficial in many aspects in AECO sectors, there are several challenges and hurdles that must be overcome in order to facilitate greater adoption of BIM in the construction industry, such as transactional business process evolution, computability of digital design information, and meaningful data interoperability (Bernstein and Pittman, 2005). In reality, the searching for the overall and effectiveness of the practice of BIM is still ongoing (Jung and Joo, 2011).

The authors believe that to tackle the barriers and issues faced by BIM, is through the usage of cloud computing or the web. It was agreed that web portals would be necessary for full collaboration and sharing of data as required by BIM (Isikdag, 2012).

Cloud computing based smart building models has also been recently been developed, as shown in a paper by Sawhney and Maheswari (2013). In their proposed framework, a cloud based framework acts as a central server where all the designs and engineering software is located. These data can then be accessed by personnel and used in a local server before being synced back with the central server. This makes it more efficient for users to coordinate using BIM. Besides, the construction industry can benefit most from cloud computing through Software as a Service (SaaS) infrastructure and data virtualisation (Underwood and Isikdag, 2011). This is because through cloud computing, all the software and hardware required can be made through the cloud with virtualisation, thus eliminating the need for companies to acquire software and physical hardware, resulting in extensive savings in cost. The cloud computing coupled with BIM could improve interoperability among BIM applications by sharing and accessing information across multiple platforms, yet security and legal aspects should be well taken care as some information can be sensitive and require confidentiality (Redmond et al., 2012).

As a result, the managerial aspects and legal issues are the main concerns for BIM in the near future. It is because existing procurement and project delivery approach have remained relatively unchanged for many decades and they should be fine-tuned to suit the different characteristics and working environments as adopted in BIM. A workable legal framework is still at preliminary stage (Olantunjil, 2011). Besides, management for BIM (BIM-M) aims to coordinate and manage overall information, process, and strategy for a whole project lifecycle, yet the implementation of BIM-M has a long way to go before its maturity (Underwood and Isikdag, 2011), particularly for on-site construction planning and scheduling (Song et al., 2012) as well as overall project management/planning in BIM projects (Shen et al., 2012).

Practitioner/Industry Perspective

At its most basic, the concept of BIM can be reduced to a database with a data structure such as IFC. Now, the base data that describes a building's form and functions are increasing, albeit relatively rarely, in this format, the opportunities and possibilities afforded are only now being ruminated on by the AECO sectors.

Until recently, the focus of the industry has been on how to make a basic BIM work, as opposed to exploring what can be achieved with BIM. This is changing as an ever increasing array of specialised products and services evolve. Particularly, it is seen in the support sector where, for example, autodesk have formed a strategic alliance with site equipment specialist, Topcon, and site equipment specialist Trimble have purchased Sketch-Up from Google and 5D BIM specialist Vico. This movement of BIM to site is being experienced in the industry, with clients at the leading edge regularly asking for support in this transition. Furthermore, increasing interest is being shown by client operators, who are beginning to appreciate the value of accurate and detailed 'as-built' models for their operations and facilities management activities. Therefore, the BIM would work better in terms of its implementation on site and overall operations and facilities management in the near future.

Next, it is probable that the project phase transition will in turn drive the use of mobile devices across the industry. As processing power follows Moore's law, powerful, mobile devices will enable designers and construction phase operatives to work effectively at the optimum location, be it site or studio. This will be enhanced by the increasing and symbiotic shift to cloud based storage and processing. Indeed, some software providers actively encourage users to export specialised processing tasks, such as Autodesk's cloud rendering system, or their Ecotect environmental analysis (and option generation) system. It is likely that, following history, the adoption of these services into a project team's workflow will experience difficulty; however, this time, the difficulties are more likely to be as a result of human resource limitations than technicalness.

Apart from that, although technology solutions are widely available, most firms still rely on traditional design and build processes. This is beginning to change as more government agencies express and interest in developing BIM-based workflows that add efficiencies to design approval and regulatory compliance. As the regulator and the largest client, this influence will permeate down to the rest of the industry and drive increased adoption at every level. This soft aspect is a significant area and would drive the BIM forwards.

Finally, the availability of library data is increasing exponentially. This is coming from two sources. The first are the in-house generated objects or families that a design practice will create for a project. Digitised information is inherently suited to copy and pasting or re-using. As design practices increase their experience, their own libraries are increasing. Secondly, equipment and product manufacturers are increasingly making their product catalogues available as BIM ready objects or families. This ability to select pre-drawn objects from a library and simply drop them into a design is bringing enormous gains in productivity, efficiency, and effectiveness. This is naturally facilitating the linking up with the extended supply chain, further driving improvement in a virtuous circle. It would be another important area of development and implementation of BIM in supply chain management.

In summary, BIM is evolving organically across a range of dimensions and building lifecycle phases. Amongst the leading practitioners, using a metaphor, BIM has emerged from a crawling phase and is beginning to walk with increasing speed and confidence.

Discussion and the Conceptual Framework

Basically, it is only recently that the concept of BIM has been able to make the transition to real-world application. Although it has been theoretically possible for some time, and projects have been developed under laboratory conditions, the barriers to live-project adoption have prevented industrial or commercial viability. One by one, the barriers of insufficient technology, misunderstood processes, and shortage of skilled human resources have been addressed.

Subsequently, the understanding of BIM has increased and developed progressively in the AECO sectors. It shows a positive growth for BIM in academia research as well as industrial practice.

The paper highlights few important implications such as:

- Four major areas of BIM are practicing and developing in the current status. They are clash detection (ICT feature within the software), constructability assessment and sequencing (it could be referred as the fourth dimension or 4D), cost estimation (5D), and facilities management (6D).
- Certain significant areas of BIM would be the future directions based on the mixed review approach in terms of implementation and development such as:
  - Use of cloud computing in coordinating all the BIM processes.
  - Improved BIM-management, particularly for the site and facilities management.
  - Effective contract administration for BIM on its overall legal structure and project delivery.
  - Innovative application in BIM with mobile devices.
  - New initiatives and regulations by government agencies.
  - Enriched BIM's libraries for supply chain management.

Figure 2 illustrates a conceptual framework for the overview of the update of BIM. The past or pre-BIM stage explains the conventional working environment in 2D mode and preliminary trial of BIM in 3D manner. Subsequently, a more collaborative and coordinated working practice has promoted and implemented. Four main areas are applied at the current state of development and implementation of BIM, namely, clash detection, constructability assessment and sequencing, cost estimating, and facilities management. Then, the forecast and future development of BIM are mainly on the cloud computing, where all the processes and an innovative tool, like mobile devices could be incorporated and coordinated at the cloud. Besides, the managerial and contractual aspects would be the focal point for an effective implementation BIM in the AECO sectors. Last but not least, it is forecasted that the government agencies would provide more initiatives and certain regulations in promoting BIM.

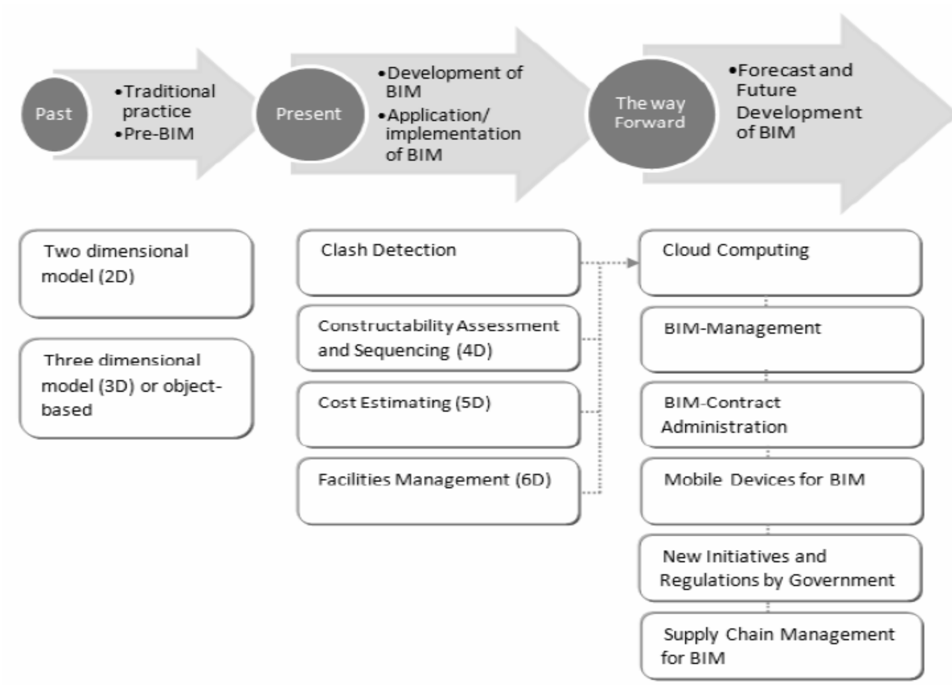

Figure 2. Conceptual framework for BIM update 2013.

Conclusion

The mixed review approach reveals that the findings are mostly complementary to each other in terms of the development and actual implementation of BIM in AECO sectors. New implications have discussed and drawn for the future directions. However, certain limitations need to be considered in this mixed review paper. The data of the review paper have yet to be verified or tested using primary data. The audience might be doubt of the message delivered in the paper. Nevertheless, the data are derived based on the mixed review approach from the updated literature and practical experience in BIM. It would improve the accuracy and comprehensiveness of the findings. Besides, some of the forecasts require further verifications and investigations, even though the inputs were obtained from the numerous years of industrial practice and observations in BIM projects.

In sum, the technology is generally fit-for-purpose, although far from perfect in terms of affordable and accessible. It is because the processes by which BIM models are generated and deployed are becoming known, understood, and codified; this can be seen by the general convergence of the plethora of BIM standards. Concurrently, the human resource capital has grown in both capacity and capability, as experience and knowledge conflate.

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