DIVERSE APPROACH OF BIM IN AEC INDUSTRY: A STUDY ON CURRENT KNOWLEDGE AND PRACTICE

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ABSTRACT

The Architecture, Engineering & Construction (AEC) industry has a long chase to overcome the barriers come from project cost overrun, poor productivity, quality, and extended time. Building Information Modeling (BIM) offers the potential approach to overcome these constraints in a highly integrated fashion with efficient and effective collaboration between all stakeholders. As a result, it has been acknowledged as one of the rising trends in the contemporary construction industry. However the potential use of BIM has not been limited only in the building construction industry, also rapidly growing for almost all type, scale and size of built environment projects. It has now exhibits promising trends to all other construction works such as bridge, roads, power plants, industry facility and so on. Moreover, the scope of work for BIM has been spread out in a large extent due to continuous research effort. Indeed BIM is now more diverse considering current context and widely known in different forms such as Green (Sustainable projects) BIM, Social (Participatory) BIM, Horizontal (Infrastructure project) BIM, Vertical (Building project) BIM and Heavy BIM (Civil Projects)

This paper aims to highlight the current state of the art of BIM diversions of the industry mainly based upon the construction types. These diversions of BIM are further generalized with reference to collaboration aspects, industry acceptance and its usage. The empirical part of the paper will coalesce BIM trends, different use and future applicability that will be a demonstration for the academics and practitioners. Furthermore it includes different survey data and case study references to exploit the rational findings of BIM.

Keywords: green BIM, social BIM, horizontal BIM, vertical BIM, heavy BIM.

1. INTRODUCTION

Construction industry suffers with a lot of problems comparing with other industries. The reasons behind these problems are unique nature of projects, paper-based drawings and fragmentation of work and activities from involvement of different discipline and stakeholders. Technological revolution has reshaped and reengineered the construction industry with new ways of working. Construction projects are unique and a prototype within themselves. Involvements of multi-disciplinary teams often make clashing among their methodologies (e.g. working process, design review, constructability etc.). Moreover errors and omissions in paper based design documents, communication gap with other stakeholders; schedule conflict, delays and unanticipated field costs are also major concern for lower productivity of the industry (Eastman et al., 2008). Besides that, the world is now changing towards a sustainable/green world and construction industry has been widely known as a major source for pollution, environmental degradation and natural resource depletion. Thus it is assumable that construction industry suffers not only with productivity or economical disaster, it also has to mitigate and maintain the triple bottom line of sustainability.

AEC industry has a long quest on implementing innovative techniques that aims to decrease project cost, increase productivity, quality, and reduce project delivery time. Two dimensional (2D) computer aided design/drafting (CAD/D) tools as digital replacement of traditional pen and paper, introduction of three dimensional (3D) CAD tools for volumetric visualization, and development of object-oriented CAD (OOCAD) platforms are some of the subsequent technological implementations for successful project execution and improving workflow of the project processes. Adoption of building information modeling (BIM) technology, the latest generation of OOCAD systems has been inevitable to meet the ever growing demand of better workflow, generating value for money, and creating sustainable solutions (Mihindu & Arayici, 2008; Arayici et al., 2009). BIM has the potential approach to achieve these objectives in a drastic manner (Azhar et al., 2008). The success of BIM practice over the construction industry has been investigated by many researchers in different projects and recommended as a remedy to address low productivity issues (Eastman et al., 2008; Mihindu and Arayici, 2008). BIM implementation and usage is gaining high momentum of adoption in the industry because of its promise of high-end results and benefits. This adoption is further boosted by government initiations in most of the countries as they today demand or plan to demand BIM based workflow for construction projects. Although the definition of BIM represents its functionality based on building construction, the functional blessings of BIM has been widely used in different fields of construction sector; in almost all kind of construction projects. BIM is now even more diverse considering current context and widely known in different forms such as Green (Sustainable projects) BIM, Social (participatory) BIM, Horizontal/Infra (Infrastructure) BIM, Vertical (high rise building) BIM, and Heavy (civil works) BIM.

2. BUILDING INFORMATION MODELING

Building information modeling (BIM) represents a virtual environment that allows all design team members (owners, architects, engineers, contractors, subcontractors, and suppliers) to collaborate more accurately and efficiently within a single virtual model (Azhar, 2011). Through BIM model, it is possible to generate the geometry and its spatial relationships, geographic information, quantities and properties of building elements that can be used for cost estimates, material inventories, and project schedule in design, construction and entire life cycle period of a facility (Bazjanac, 2006).

Eastman et al., (2008) defines BIM as "*a verb or adjective phrase to describe tools, processes, and technologies that are facilitated by digital machine-readable documentation about a building, its performance, its planning, its construction, and later its operation*". It is also stated that, BIM is a virtual model of a building that contains precise geometry and data for getting optimum design, procurement, fabrication and construction activities required for a project. It is important to note that BIM is not just a software; it is a process that runs through software. BIM- based projects do not mean only using three-dimensional intelligent models but also brings significant changes in the workflow and project delivery processes (Hardin, 2009).

Building information modeling is an intelligent process for product visualization, automatic fabrication/shop drawing, cost and material procurement, construction sequencing, conflict or collision detection, forensic analysis and facility management (Azhar, 2011). These models have intelligence within itself; one single change in any part is simultaneously updated in all coordinated documents. The ability to use BIM to virtually construct a building prior to construction of the real facility brings an opportunity to check its constructability in the real world and mitigate any drawbacks or any uncertainties during the entire process. Therefore it creates efficiency in work, optimize design solution for limiting waste of resources, energy usage, and enhance passive design strategies (Bynum et al., 2012).

3. PERSPECTIVE OF BIM PRACTICE

Most industrialized countries seem well informed about cutting-edge BIM technologies, BIM processes, protocols and problems, and the promoted advantages of its use (CIBER, 2012). Over the last couple of years Finland, Sweden, Norway, Germany, France, Singapore, U.K, U.S.A, and Australia made an extensive research on BIM through various mega pilot projects. Many projects have been proven as successful in terms of environment friendly design and productivity compared to non-BIM initiatives. Tocoman Professional Services of Finland

(Tocoman, 2010) claims that they have facilitated over 200 projects each with reasonable savings due to the utilization of BIM within building construction lifecycle activities, producing significantly better infrastructures with improved stakeholder satisfaction (Arayici et al., 2009). The U.S. General Services Administration (US-GSA, 2008) notified the requirement of utilizing IFC model server standards in October 2006. BIM authoring tools - Autodesk's ADT, Autodesk's Revit, Graphisoft's ArchiCAD, Bentley's Architecture, and Onuma Architecture and Master Planning were the initial tools that passed this certification through testing in 10 different pilot projects (US-GSA, 2008) and the continual development of modeling requirements proceed further (Arayici et al., 2009). Norway is considered as one of the world leaders in BIM adoption. Akershus Hospital is an example of multifunctional use of BIM for completing a hospital project. Among the industries, Skanska (construction firm in Europe) is now embarking on BIM all over the projects around the world (BuildingSmart Newsletter, May 2012).

Another Nordic country, Finland has also been regarded as pioneer in BIM research and development. From 2001, they are exploring new horizon of BIM implementation and advantages. Aurora 2, a mixed-use facility at Joensuu University demonstrates how BIM can develop cost and energy savings in building projects. Finland is also pioneer to demonstrate BIM as Governmental requirements through Senate Properties (Finnish property service agency) that required IFC based BIM or in other words openBIM in all public sector projects. Recently (March 2012) they upgrade their BIM requirements and made it mandatory for architecture, mechanical, structural and construction team to follow in projects. Moreover, Kari Ristolainen certified BIM by stating that "*At Senate, we believe that BIM is the key to cost-efficient and energy-efficient buildings and is part of high quality design and proper FM*" (BuildingSmart Newsletter, March 2012). Currently, in Finland, Built Environment Process Re-engineering (PRE) -research program with target to field of processes and operations models, has the objective to improve productivity, quality and occupational health of processes of the real estate and construction sector through utilization of new technologies, especially BIM (Salonen and Kuusisto, 2012). BIM adoption and utilization is growing rapidly all over the world. Its rapid adoption is often a result of government initiative strategy. Since 2007, Denmark government required IFC BIM for their public projects. Similarly in Netherlands, BIM has become a mandatory requirement for central governmental projects. U.K government has 5 year plan to implement BIM in the public sector projects by 2016 with a target to minimize life cycle cost by 20%, and 80% reduction in carbon emissions by 2050. To emphasize U.K BIM practice, Paul Morell, the government's chief construction adviser stated that "*This is the time for BIM*" (BuildingSmart Newsletter, November, 2011).In Asia, Korea and Singapore takes the lead on BIM. Today nearly 25-30% construction firms are using BIM in Singapore. Public sector helps to promote BIM in all level through training, certification and incentives. For that Singapore Building and Construction Authority (BCA) initiates workshops and road shows to bring changes towards BIM. They also developed ePlanCheck system that checks the building code for regulatory approval (Mihindu and Ayarci, 2008). Korea Public Procurement Service initiated Open BIM from 2012. They organize different research and training program on development of BIM through collaborating with Georgia Tech and other BIM research group (BuildingSmart Newsletter, November 2011).

New innovations have not been always welcomed by construction industry because of prevailing high risk and diverse fragmentation of construction projects. BIM started to take its steps at the beginning of 1990. It has come a long way to establish the myth that it is worthy for business and for the social responsibility. A research conducted by Fleming Vestergaard (assistant professor, Technical University Denmark) proves the benefit of BIM through four different sized project (BuildingSmart Newsletter, May 2012). The results of the research shows that first project of DKr 1.8 million saved 10% for owner, the second one worth of DKr 100 million (New HQ for Engineering consultant Ramboll) provide direct benefit DKr 3.8 million. In the third case, bid reduction was done by 15% and in the final one due to shifting the technology (from 2D to BIM), construction company Højgaard (billion kroner KPMG's new HQ project) considered it as an investment, not a project cost. Moreover, Peter Hauch of Arkidata concludes, "*The more you invest in BIM competence and collaboration, the more you get back"* (BuildingSmart Newsletter, May 2012).

4. DIVERSATION IN BIM PRACTICE

Building information modeling initially generates the idea that it would be the technology for smart, high performance or green building. But it is obvious to add that BIM is not any particular software or methodology that suits only for buildings. BIM has the concept of virtual modeling that can be utilized not only in vertical projects (building); but is also simultaneously beneficial for other built environment projects. BIM has been progressively used for different types of projects like transportation projects (Wisconsin DOT project), airport projects (Delta airlines redevelopment at JFK), transit projects (Vivanext Bus Rapid Transit system project in Toronto), dam, canal, and levee projects (Panama canal $6 billion dollar expansion project), water and waste water projects (Arbennie Pritchett Water Reclamation Facility), energy projects (Mortenson construction wind tower project), park and recreation projects (Scioto riverfront, Ohio project), sustainable projects (U.S air force base extension project, Dallas) and so on (McGraw-Hill Construction, 2012). All of these projects achieved excellence through BIM implementation. The adoption of BIM towards all kind of infrastructure projects is increasing day by day. As reported by McGraw-Hill Construction in Smart Market Report (2012), almost 46% firms are now currently using BIM in their infrastructure projects. Through BIM utilization in infrastructure projects, it is possible to reduce conflicts and changes in the design (around 58%), improve project quality (48%), lower project risk and better predictability of project outcomes (60%). SmartMarket report shows that by using BIM in infrastructure projects both A/E firms and contractors gain a new marketing benefit, overall better project outcomes, reduce error in documents, introduce new services, reduce rework and overall improve the productivity.

4.1 Vertical BIM

Vertical projects largely deal with building structures that stand above ground and grow vertically. Although each and every construction project is unique and location specific, construction processes in the world of vertical buildings can often be repeated and repeatable (Cylwik and Dwyer, 2012). BIM adoption and developments were primarily focused in managing this type of vertical projects and is considered as an important strategy today for vertical construction. In the beginning of BIM, most of the idea around its generic function, tools and software were developed considering vertical building industries. BIM tools and techniques have been organized in such a way that suits highly for these types of construction. BIM software vendors are also competing themselves for introducing new features each day considering building industry. Therefore it can be argued that vertical industry benefits mostly from BIM as its workflow supports inception to post construction of a vertical project. It supports building industries to improve productivity and as well profitability. Moreover the lessons learnt from Vertical BIM have resulted in the likelihood of quick adoption of BIM for Infrastructure/Horizontal BIM (McGraw-Hill Construction, 2012).

BIM has the ability to virtually construct a building prior to construction of the actual building. As a result for the stakeholders, it creates a way to check its constructability in the real world and make quick and precise decisions for creating a better design solution that limit waste of resources, optimize energy, and promote passive design strategies (Bynum et al., 2012). Moreover, BIM has the potential approach to integrate and incorporate individual building tasks that are crucial for AEC projects (Krygiel and Nies, 2008). Features of BIM that is incredible for AEC professionals include "*the ability to (1) support distributed work processes, with multiple team members working on the same project as well as preliminary conceptual design modeling; (2) generate highly photorealistic renderings and animations; (3) integrate the three-dimensional (3D) model with cost estimating, energy analysis, project management, and structural analysis applications; (4) use BIM's multidisciplinary capabilities to serve architects, structural engineers, and mechanical, electrical, and plumbing (MEP) professionals; and (5) provide support for construction-related tasks such as quantity take-off, estimating, and four-dimensional (4D) scheduling*" (Khemlani, 2007).

With the increasing fields for construction industry, AEC professionals and researchers are gaining new experience and open new horizon for BIM implementation. Central Park Tower at Interlocken (Broomfield, Colorado) a 11 storey, (305,000 sq. ft.) office building implementing BIM in construction have positive results, some of which are of 21.6% less reinforcing material saving nearly $113,000 for owner, reduction in construction schedule reduced by two weeks to date and 500 working hour saved for which reduced steel fabrication by 5 weeks. Due to model checking in the design phase they made zero changes design order in the construction phase. Overall, this BIM implemented project saved 10 weeks of time and had a total benefit of nearly $600,000 in value (Evans, 2011).

4.2 Horizontal BIM

In recent years, BIM has become a vital strategy for horizontal (Infrastructure) projects such as bridge constructions, road- highway constructions, rail-aviation facilities, offshore facilities etc. to improve productivity and return on investment (ROI). Around 50% of the infrastructure firms are now utilizing BIM tools and techniques in different phases of the project in different ways. According to McGraw-Hill construction (2012), around 59% used BIM for dam projects, 58% for waste treatment plants, 59% for rail, transit and aviation projects, 58% for energy projects, 56% for public parks and recreation projects, 56% for bridges, roads and highways and 57% for water related projects. Infrastructure projects have similarities of stakeholder and construction workflow with vertical projects. As a result, there has been a quick and wide adoption of BIM in infrastructure projects to overcome problems similar to the vertical projects (such as collaboration, visualization, extended construction period, clashes in different phases etc.). Contemporary BIM solutions are also solving different infrastructure problems through a collaborative approach with other technologies such as GIS data, laser scanning data, augmented reality and so on.

Crusell bridge (cable-stayed) in Jätkäsaari Island, Helsinki, is a crucial example of BIM utilization in infrastructure projects. This bridge, 175 m long and 25 m wide with two asymmetrical cable-stayed spans, measuring 92.0 m and 51.5 m (the total length is 143.5 m), and a traffic clearance width of 24.8 m was designed by WSP Finland and constructed by Skanska Civil. BIM has been implemented both in design and construction phase. Design team of the bridge used a holistic modeling approach for all accompanying structures on the shore and contains all structures related with bridge. All concrete structures were modeled, including reinforcement bars. These modeling data was used for fabrication and monitoring the quality of the fabricated components. Besides that laser scanning data for quality control and 4D animation for maintaining the supply chain and construction planning was performed. Various software applications were used through the four different project phases of the Crusell Bridge. In the whole design and construction phases, collaborative BIM approach through Tekla Structures was used for sharing and synchronizing the model over the Web, 4D planning, synchronization of the model with suppliers' factory management software, and export of fabrication data directly to computer-controlled CNC machineries. Moreover, other BIM solutions such as Vico Control and for data exchange Trimble Realworks, PERIC ad, Reinforcement List v3.1 and fabricators' ERP systems were used with positive outputs (Tekla, 2013a).

Wisconsin Department of Transportation takes a leapfrog of introducing BIM techniques and tools in roads and highway projects. They used BIM in Mitchell interchange ($162.5 million) and Zoo interchange ($1.7 billion) road projects for visual simulations, clash detections during design phase and 4D scheduling and 5D cost control were implemented in the construction phase for better control to the project time and budget (McGraw-Hill Construction, 2012). Among other infrastructure projects North Field Offshore Facilities, Doha, Qatar is also an impressive example consisting of 3-jacketed platforms and 2 jack-up barges converted to production and leaving quarters platforms for AL Karkara and North Field Offshore Facilities. Various benefits of BIM application were used for activities like detailed design and modeling. Through Tekla Structure, all shop drawings for the jackets; boat landings, topsides, helidecks and bridges were generated. Moreover for the construction management, bill of materials, clashes between the mechanical and structural model were also reviewed through Tekla Structure (Tekla, 2013b).

4.3 Heavy BIM

Construction projects are different and unique according to size and nature of the project. Amongst, projects relating to civil work require heavy equipment and complex procedure to design and construct. These projects are highly challenging for their enormous size, adverse site condition and complicated design. The civil projects referred to as heavy projects are construction of tunnels, dams, spillways, reservoirs, foundations, mass transit stations and marine works. To solve the complexity of heavy projects, BIM plays a vital role through its different functionalities (such as 3D visualization for design review, collision check, 4D simulation to track project progress and so on) similar to vertical and horizontal construction works. It brings an emerging trend in the heavy civil disciplines through valuable applications toward arrangement of new opportunities.

State Route 99 Tunnel project, Alaskan way viaduct, Seattle, Washington is an example of BIM implementation in heavy civil works designed by HNTB. BIM visualization was implemented at the earlier stage of the design of this 16-meter inside diameter bored tunnel project beneath downtown Seattle. The construction of this tunnel is an extremely complex task that combines civil engineering, structures, architectural, mechanical & electrical systems, and traffic management. Different design alternatives were analyzed through visualization and later on the deep bore tunnel as a solution was chosen. Tekla BIMsight used by HNTB helped the professionals to combine models from all disciplines and view models with smooth navigation features and capture areas of interest with ease. Utilization of model-based communication was used in weekly all-discipline coordination meetings as collaboration tool with all the stakeholders. Due to merge of different models in Tekla BIMsight, HNTB and project participants were able to see conflicts and possible design changes through quickly cut sections and turning on and off of the model elements. Moreover different analyses were done at the design stage such as daylight analysis, also 4D scheduling construction sequencing for optimum construction period (McGraw-Hill Construction, 2009).

Empresa Electrica Guacolda S.A (Energy generate and transmission company, Chile) operates a coal-fired power generation plant located in Huasco, Chile that is another example of BIM in heavy projects. The construction of this project was carried out by Mitsubishi Heavy Industries (MHI), and Edyce. For the whole construction process they used Tekla Structures actively for modeling purposes and sharing necessary on site and off site data. Through BIM based workflow, they managed to overcome their respective time differences, distances and language barriers to achieve a remarkable improvement in the transfer of operational data. BIM utilization in these types of projects have benefits of enhanced work flow, minimization of schedules, increase in safety, and provide a better end product, or increase field productivity (Tekla, 2013c).

4.4 Sustainable or green BIM

Sustainability or sustainable construction is now a dominant issue for the AEC sector. Green BIM denotes the contribution of BIM to achieve green or sustainable construction. Early collaboration and open information sharing among all team members is one of the key factors for achieving sustainable built environment in construction projects. Use of BIM in green projects support to achieve sustainable goals in an intense way (McGraw-Hill Construction, 2010). Moreover, green practitioners found synergies between Green and BIM. A study organized by McGraw-Hill Construction (2010) shows around 27% green BIM practitioners believe that BIM is highly applicable to achieve green goals, and around 49% believe it has medium influence for getting green or sustainability goals. It furthermore exhibits around 78% of the BIM users who do not currently use it for green projects expect to be doing so within 3 years. Green building today is considered as a standard practice in most of the countries and the growth is undeniable; as for example, US Green building market has grown from 2% in 2005 to 44% in 2012 and in Europe from 11% in 2008 to 29% in 2012 (McGraw-Hill Construction, 2013).

Currently BIM tools are actively used for passive design simulations for generating better solutions. BIM applications today are capable of enabling sustainable design by integrative BIM and are widely used for implementing passive design strategies through study of building orientation, building massing, day lighting, water harvesting, energy modeling, and implementing renewable energy strategies (Krygiel and Nies, 2008). Through these various simulations and analyses, requirements for heating, cooling, ventilation and electrical loads will cut off in large scale. In this regard, Palomar Medical Centre West (2007 – 2011) is a good example of Green BIM. During the early stage of the project, stakeholders had an integrated green approach and strategy to implementing sustainable solutions. To demonstrate BIM importance on green project Frances Moore, AIA, LEED AP, CO Architects associate principal stated that, *"You could design a sustainable building without BIM. But what you can't do is design and construct it in a truly sustainable way that goes above and beyond the traditional approach, such as use of LEED checklist or the Green guide for health care"*. For sustainable or energy efficient projects several research organization has been found by government and non-government initiatives. LEED is such an organization that provides certification for energy efficiency and as well sustainable construction. It has total 69 points, which can be achieved through following guidelines of LEED. These points are divided for sustainable sites, water efficiency, energy and atmosphere, on site renewable energy, materials and resources, indoor environmental quality, innovation and design quality. These points or credit calculations can be done more effectively through BIM models. McGraw-Hill Construction (2010) reports usefulness of BIM in calculating LEED credits; Around 42% Green BIM users believe that technology has medium to high usefulness for credit calculation, 38% believe it has lower impact and 20% has find no value for this. Currently using Revit product, nearly 54 points can be calculated for LEED NC 2.2 (Fisher, 2009) and full integration of generating BIM based documents for LEED certification is an on-going effort in Green BIM. Charles Matta, National Director, Strategic Programs & Professional Resources, U.S General Service administration states that BIM assists in improving sustainability and energy use in facilities from very early stage of planning and design and in construction component through BIM energy analysis and daylight analysis; and currently an extensive research on BIM is being carried out for creating a BIM guide for energy performance, operation and maintenance that holds a strong vision on sustainability (McGraw-Hill Construction, 2010).

Shanghai tower is another marvelous demonstration for Green BIM practice from Asia. From the inception of this project Shanghai Tower Construction & Development Co. Ltd, the design architect (Gensler) and the owner comprehend that BIM and integrated design approach were prerequisite for dealing with the complexity of design, effective collaboration and better sustainable outcomes (McGraw-Hill Construction, 2010). Utilization of BIM data is moreover planned for the tower's daily operation, equipment management, real estate management and emergency management. BIM not only helped the project design team to select the optimum tower design that reduces the wind load by 24% (each 5% reduction equates roughly about USD $ 12 million), it also optimized the amount of material in use (14% less glass compared with square building with the same area (Xia et. al., 2010).

Sustainability issues are more and more focused in BIM technology. BIM data can primarily be used to exchange building property data for accurate sustainability analyses to other third party applications through IFC formats that is also primarily used for data exchange between various disciplines. Full sustainability assessments within BIM applications are not yet possible and the road from building information modeling to building energy modeling (BEM) is a central focus today. Final reports of SuPerBuildings (2010-2012), a research funded by EC under the FP7 Cooperation states that, in the recent update (IFC4), it has made a significant step forward towards BIM and sustainability indicator integration. This BIM centered approach results in multiplying the interests for the integration of nD digital mock-ups in the use of sustainable building rating and benchmarking systems in different stages of building processes in multi-discipline and multi-stakeholder environments (SuPerBuildings, 2012).

4.5 Social BIM

With the diverse approach of technology in construction world, integrated workflow is often recommended for success of the projects. In other words, construction professionals need to embrace socializing aspects of undertaking the project by actively sharing project data between the project participants. Social BIM is often named for these types of collaborative approaches and terms like "collaborative BIM"; "integrated BIM (iBIM)" are often used. Social BIM is also seen as the social dimension of BIM representing collaboration aspects of the industry within different stakeholders. The process of transition from traditional CAD method can be described through four different terms as described by Banks (2013): Lonely little BIM – where BIM authoring tools are used primarily for generating traditional printed set of documents; social little BIM – sharing the little BIM information with collaborators through basic 3d data exchange to other author tools and dynamic visualization platforms; lonely BIG BIM – that goes beyond visualization utilization BIM for energy analyses, cost calculation, schedule generation are performed for internal purposes but data is mostly shared with 2d backgrounds and printed sets; and social BIG BIM – which is considered as the real BIM and all possible utilization of BIM is performed for projects in an integrated way of collaboration.

Social BIG BIM encompasses utilization of nD models that are actively shared with the project participants and include full data sharing and integrated collaboration for life-cycle purposes with an aim to achieve maximum benefit that BIM provides. This phase also includes utilization of different forms of IT applications like virtual reality, augmented reality, and mobile technology for the users to actively connect with the building and products. Some of the possible fields include, smart building interaction of building systems for users and access through mobile devices, use of augmented reality for generating information about building or building elements, real time information applications for the users and owners in case of disasters like fire and so on.

Users play a vital role in defining social aspects of BIM. Professional collaboration today is possible in many ways with introduction of technological developments and its incorporation. Rapid development of web 2.0 technologies has furthermore provided an opportunity for the involvement of building users to actively participate in construction projects from very early start. Users hold a unique knowledge and its translation into a consistent design requires a systematic and coherent approach to user involvement (Christiansson, 2011). Social media, the commonly accepted platform to share, connect, and collaborate may help this approach and these type BIM process technology with a central importance to user participation has been termed as "Social BIM 2.0" (Jäväjä et. al., 2012). Social media technologies integrated with BIM not only provides industry professionals to actively participate end users in developing better built environment solutions but also helps in creation of new business innovations like model based web platforms that could easily be mixed with prevailing organizations for even more easy, better and efficient workflow.

5 DISCUSSIONS AND CONCLUSIONS

Currently BIM is mostly used in design and construction phases of the construction projects. BIM based operation and maintenance phases of the project considering the whole life cycle of building are currently mainstreaming in both academics and industry. Various issues still lie ahead for development and perfection in all the phases. Integrative technological innovations of the construction industry still seek for coordinated research for BIM throughout the project life cycle. Some of the prime issues and current need of focus are presented through the following paragraphs.

Construction is not only a matter of technological improvement. It has, triangulation between social, environmental and economical relationships. The scenario of construction industry is not same all over the world, and so is the adoption of technological aspects of BIM. Lack of awareness, initial higher cost, and education are the common barriers for BIM augmentation in many countries. Extensive research on BIM and BIM based technical education can only break the isolated system. However there is a huge gap in BIM related training and education and no consistent demand is there for BIM skilled and knowledgeable professionals (Kiviniemi, 2013). Kiviniemi (2013) further points out the needs to standardize or certify BIM knowhow and skills across the construction with the lack of skilled BIM professionals, educational organizations should fully embrace BIM into their curricula. For that several renowned institutions are now introducing BIM as a course work, however very limited institutions have full BIM packages. Thus there is a need of formulating BIM based research on how BIM should be efficiently and effectively taught to educate both old and new generation professionals.

Interoperability is another major concerning issue for accurate transfer of data communication between various discipline and tools of project participants. Different vendors provide different BIM applications and all of their data are not interchangeable. Furthermore, IFC standards have been primarily focusing in building construction domain and other BIM application fields are not so much focused. Different software vendors are trying hard to establish connectivity between BIM process and analytical tools. However data translations between several tools are major challenge for the vendors. Don McLean, president and founder of Integrated Environmental Solutions believe that current data translation qualities are not in a satisfactory level which can be overwhelmed in BIM. On the other hand BIM vendors are not satisfied yet with their BIM software. As Miklos Sved, product development manager at Graphisoft states that, "*there are isolated tools in the market that claim they can do this, but a tool that provides a seamless workflow from the building information model - all the way to accurate lifecycle analysis has not been developed yet"* (McGraw-Hill Construction, 2010).

Green BIM is denoted as sustainable practice form of BIM. Architects are currently showing greater interest on green BIM practice while owner demand will boost up this scenario. The key to attract on green BIM are governmental legislation, knowledge on green BIM that reduce life cycle cost in the operation and maintenance phase, continuous research on developing new methodologies and so forth. Nevertheless the main barrier for Green BIM adoption has been identified as limited analysis competences of BIM applications. Through different software integration, integrated design decision considering multiple parameters, modeling standard set up, building performance monitoring and verification, use of BIM in small green retrofit projects seems to be the remedy for green BIM practice (McGraw-Hill Construction, 2010). Green BIM practices have to break the barrier of considering it only for design stage which is currently practiced. Therefore future research is a dire need to imply BEM on different project phases (such as planning, construction, post construction) to enhance the value of sustainability.

It is necessary to inter-connect processes, technologies and organizations for successful construction projects (JBIM, 2012). Manufacturing industry has shown a dramatic improvement through shifting their process as mass to lean production. Lean principles applied for construction industry may also prove to be beneficial to enhance improvements in workflow of the construction processes. Lauri Koskela (2010) defines lean construction as a production theory and BIM as a product representation. Rischmoller et.al., (2006) also point out strong synergy between lean construction principles and computer advanced visualization tools (CAVT). In a study of Lean and BIM relationship, Sacks et al., (2010) listed 24 lean principles and 18 BIM functionalities and identified 56 explicit interactions between them, of which 52 were positive interactions. Through using Lean construction principle in construction, BIM shows a productivity alteration. It has to be remembered that BIM is a technology that needs a correct process to run and lean is a process that need correct technology to boost up. Therefore, a proactive research is needed to test the actual synergies of Lean and BIM that could mutually contribute both fields.

The plethora of terms used for BIM depending upon the projects refer to the same capability of creating data-rich intelligent models to facilitate better workflow of construction processes. Integrated BIM process and technology provides or aim to provide possible solution for most of the construction project types from its early conception to the end of its useful life, retrofitting of the product and finally its demolition. BIM plays a vital role in organizing the processes involved within this project life cycle through enhanced construction efficiencies, and active collaboration between the stakeholders involved through sharing of intelligent data over various disciplines. BIM is a socio-technical system and technological interventions in construction industry will create new business opportunities and solutions. Possible research areas identified in the paper calls for a coordinated research to make BIM even better than today.

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