World Academy of Science, Engineering and Technology
International Journal of Structural and Construction Engineering
Vol:15, No:11, 2021

Sustainable Engineering: Synergy of BIM and Environmental Assessment Tools in the Hong Kong Construction Industry

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***Abstract*—**The construction industry plays an important role in environmental and carbon emissions as it consumes a huge amount of natural resources and energy. Sustainable engineering involves the process of planning, design, procurement, construction and delivery in which the whole building and construction process resulting from building and construction can be effectively and sustainability managed to achieve the use of natural resources. Implementation of sustainable technology development and innovation, adoption of the advanced construction process and facilitate the facilities management to implement the energy and waste control more accurately and effectively. Study and research in the relationship of BIM and environment assessment tools lack a clear discussion. In this paper, we will focus on the synergy of BIM technology and sustainable engineering in the AEC industry and outline the key factors which enhance the use of advanced innovation, technology and method and define the role of stakeholders to achieve zero-carbon emission toward the Paris Agreement to limit global warming to well below 2°C above pre-industrial levels. A case study of the adoption of Building Information Modeling (BIM) and environmental assessment tools in Hong Kong will be discussed in this paper.

***Keywords*—**Sustainability, sustainable engineering, BIM, LEED.

I Introduction

THE process of building and construction in residential, commercial, infrastructure and refurbishment requires different elements varied from natural resources like timber, water, sand and non-renewable energy including petroleum and electricity for construction process. The construction industry plays as a key contributor in carbon emission, waste generation and pollution [11].

Sustainable engineering is often ignored in the building and construction industry in view of the rapid demand of housing development and the need for quick product delivery. The stakeholders in the construction industry have adopted the conventional concept for “time, cost and quality” in the past. However, with the fast development of technology innovation and increase of global concern of climate change, the concept shall be redefined to include sustainability i.e. time, cost, and quality and sustainability.

The promotion of sustainability required different stakeholder’s effort from small to large scaled developers with clear government policy, client vision and supply of high skilled expertise of A/E building professionals.

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II Green Building

Sustainable engineering is a revolution and turning point of the construction industry which plays a key role in design, fabrication and delivery of high quality sustainable building and infrastructure. It includes two major elements, innovation technology and sustainability tools which are interrelated. Research and development of innovative technology and sustainability assessment tools is the key to improve and meet the rapid changes and demand for sustainable development in the construction industry and community.

Innovation technology comprised 1) the development of computer software like Building Information Modeling and Cloud Services, 2) advanced construction methods like DfMA, MiC, 3) Embodied and Upfront Carbon.

A. Building Information Modeling (BIM) and Cloud Services

The benefits of adopting BIM can significantly reduce errors, reducing unwanted rework on site and hence, increase the collaboration of different stakeholders: A/E, contractor, client in management and productivity in turn the target of high level of time, cost and quality control can be assured [15]. The development of BIM in developed countries during the past 10 years has seen a breakthrough from conventional 3D/4D level BIM for crash analysis then up to 5D/6D/7D level BIM (Fig. 1) to achieve higher levels of benefits [7], [13]. The 5D BIM can achieve more cost control aspects while further wide adoption of 6D BIM can greatly achieve the sustainability goal. Client, A/E and Contractor can share their latest construction information by using the cloud storage which enables all parties to monitor the quality and progress by using cloud services to share ideas and make necessary decisions faster without face-to face review on site.

Early adoption of BIM in the conceptual stage can help the A/E to coordinate the project effectively and enhance client communication to meet actual client expectation. For complicated projects [1], the BIM model can also be used for collaboration with other consultants to carry out different environmental studies and share innovative ideas including facade material selection, sustainable design elements to achieve required sustainability design and assumption [9].

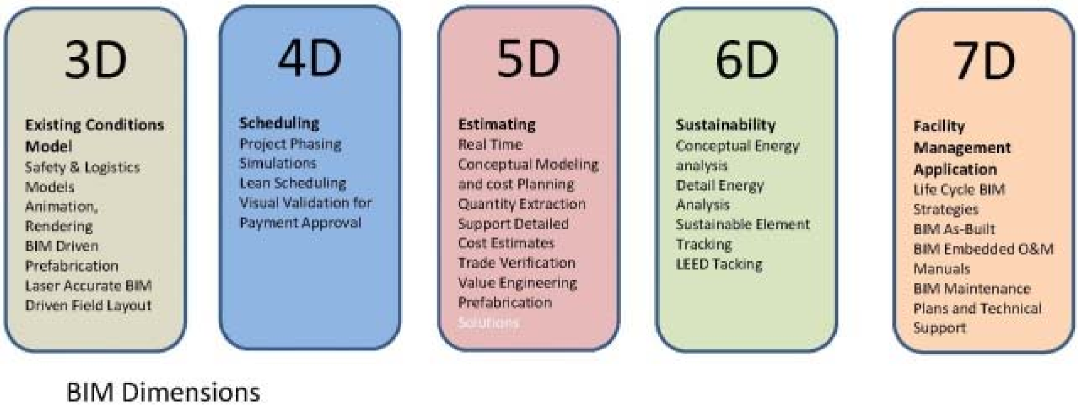

Fig. 1 Graphical illustration of BIM dimensions

B. Design for Manufacture and Assembly (DfMA)/Modular Integrated Construction (MiC)

Early adoption of BIM in the design stage can facilitate and streamline the process of design and future manufacturing and installation [16]. Modular integrated construction design with the aid of high level of BIM technology can minimize the resources and demand of skilled labour and different trades including MEP can be manufactured and fabricated in offsite prefabrication factories independently to achieve centralized material storage, recycling and waste sorting in specific trade factories effectively. Promotion of the use of renewable energy in prefabrication factories also encouraged the adoption of renewable energy. Different components can then be accurately fabricated in individual factories up to the required standard [18], [19] under a controlled environment before delivered to the prefabrication factory for assembly and delivery to site for immediate installation. This can reduce the unwanted pollution, material wastage and enhance the control of time, cost and site safety [17]. Point-to-point construction also reduces the unnecessary pollution generated at those pollution sensitive construction sites and shortens the overall construction cycle.

C. Embodied and Upfront Carbon

The construction process contributes a significant part of carbon emissions during the manufacturing, transportation and construction. In the early design stage, the selection of net zero embodied and upfront carbon to achieve the decarbonization [4] by using the local and internationally recognized environmental assessment tools including BEAM Plus (HK), LEED (US), WELL (US), Green Star (Australia), BREEAM (UK) for proposing a best practice embodied carbon reduction strategy and monitoring the whole construction process and final performance of buildings and infrastructures.

Sustainability tools include two major aspects: 1) sustainable procurement and 2) adoption of internationally recognized environmental assessment tools and certification including LEED, WELL or other similar to achieve effective and efficient sustainable design and energy conservation and waste minimization and management.

D. Sustainable Procurement

Sustainable procurement with reference to ISO 20400 becomes the growing trend in the building and infrastructure construction field [12]. All practitioners in different organizations involved in the projects should be fully aware and committed to sustainable procurement technology. Perhaps, it is hard to achieve in terms of culture, business model and commercial decision. With the assistance and promotion from government, practitioners are now willing to adopt and build a sustainable supply chain for the future and make the commitment to social responsibilities.

E. Environmental Assessment Tools, Methods and Certification and Innovation

There are various environmental assessment tools and certification developed in different countries (BEAM Plus (HK), LEED (US), WELL (US), BREEAM (UK), Green Star (Australia)) but the common goal of adoption of various tools is to meet the global trend to reduce environmental impact and achieve sustainability during construction and operating cost particularly in significant cost saving on energy and water. The combination of use of the environment assuagement tool and building information models (BIM) create a synergy to achieve a high standard of sustainability [2]. The BIM model can be used in the design stage with the assistance of different computational simulation tools to ascertain the design assumption made in environmental assessment tools and monitoring the whole construction process which can be in line and meet the requirement under regulation and client expectation.

One of the major advantages in environmental assessment and certification is their encouragement of innovation of building design, technology and construction methods and it plays an important role in the promotion of technology development.

III. Diversification of Sustainable Engineering Knowledge in Architecture/Engineering/Construction Field (AEC)

There are so many brilliant architects, contractors and consultants out there but actually bringing the integration of architecture, engineering and sustainability to real life proves to be quite rare. AEC practitioners are usually specialized in their knowledge learnt from university and gained professional skill in their practice in specific fields. Most of universities with engineering programs mainly focus on energy efficiency as an indicator of the course in sustainable engineering with a high variable of contents in topics across departments and universities.

Universities should formulate and tailor their courses in the front line to line up with the future market need of BIM and sustainable engineering. For practicing AEC practitioners, professional institutes should also take the lead role to promote and accelerate the top up training to the partitioners to diversify their knowledge and skill in the area of BIM and sustainable engineering in order to fill the gap [5].

IV. Government Policy

In Asia, the construction industry contributed GDP in different countries: 4.2% in Hong Kong [20], 9% in Australia, 2.7% in Singapore and 5.3% in Japan. The carbon emissions and sustainable construction therefore cannot be overlooked. For example, the Hong Kong government has implemented different short- and long-term policies and incentive schemes to deal with the impacts of climate change. The government plays an important role and leading position to deal with the impacts of climate change and zero carbon emission. In Singapore, the Singapore‘s Building and Construction Authority (BCA) had issued an official guideline for DfMA with incorporation with Building Information Modeling in 2016. In 2018, the Hong Kong government, Development bureau developed “Construction 2.0” [6] to enhance the construction industry’s sustainability and long-term growth prospects and promote the use of DfMA and MiC. The Hong Kong government had the key function to formulate different regulations and standards to promote the adoption of sustainability by means of incentive for relaxation of development potential, building design parameters, administration procedures [10], [14] like the prerequisite of adoption of environmental assessment tools to meet certain standards prior to obtaining consent for commencement of building proposals [3], [8] and support from government to adaption of low carbon embodied construction activities and fulfill the commitment of reduction of greenhouse gas emission by 2030.

V. Client Vision

The importance of client vision in construction to innovation and sustainable engineering cannot be overstated. The demand for high efficient and intelligent buildings by community and government plays a driving power to the development of more energy efficient and environmentally-friendly buildings and infrastructure. More and more new building and infrastructure development particularly in Hong Kong achieved the highest local and internationally environmental assessment rating. In 2021, there are about 110,000 newly developed residential, commercial and government buildings and infrastructure projects that participation in the most widely used international environment assessment standards, “LEED”. With the client vision and mind set being changed, the attention to corporate image as well as time, cost, quality and sustainability become more important and prominent.

VI. Case Study

A. Collaboration of BIM Technology and Green Building Design Through Environment Assessment and Certification, King Wah Road Eighteen, Hong Kong

TABLE I
Particulars of King Wah Road Eighteen

Project Information	Internationally Recognized Outstanding Achievement
Owner : Henderson Land Development Design Architect : Pelli Clarke Pelli Architects Project Architect : DLN Architects Limited Type of Building : Grade A High Rise Office Building GFA : 30,635 sqm Completed in 2017	• Platinum Standard Rating under BEAM NB version 1.2 • Pre-certification Platinum under LEED BD+C : Core and Shell (v2009) • 3-Star Award under Green Building Design Label • Grand Award in the Hong Kong Non-Residential (New Building – Non-Government, Institution or Community) category of the Quality Building Award 2018 • Merit Award of Hong Kong – Commercial Building in recognition of Excellence in Architecture of The Hong Kong Institute of Architects (HKIA) • Merit Award of Hong Kong – Commercial Building in recognition of Excellence in Architecture of The Hong Kong Institute of Architects (HKIA) • Merit Award in in New Building Category (Building under Construction) of Green Building Award • 2017 Excellent Intelligent Green Building, APIGBA Hong Kong Award under Asia Pacific Intelligent Green Building Alliance (Hong Kong Region) • Silver Award under HKIA CADSA Design Award 2019

King Wah Road Eighteen is an iconic and renowned commercial building in front of Victoria Harbor. The US-based designer American architect Cesar Pelli from Pelli Clarke Pelli Architects and project architect “DLN Architects Limited” worked together and completed the project in 2017. The project team adopted 5D/6D BIM Modeling and Leadership in Energy and Environmental Design (LEED) (US Green Building Council) in the design stage with the implementation of different other internationally recognized environmental assessment methods including Green Building Design Label (GBDL) (China Green Building Council, Green Building (Hong Kong) Council), WELL Building Standard (WELL) International Well Building Institute (IWBI), Building Environment Assessment Method (BEAM Plus) Hong Kong Green Building Council and obtained the highest internationally recognized standard of green, intelligent and substantiality building design. The BIM also served as a monitoring tool to keep track the LEED rating achievement during design and construction phase.

With different site constraints and regulation restrictions, the team based on the BIM analysis result and articulated the building design with curved building surface, setback and provision of air corridor at ground floor to enhance the air ventilation, maximize the landscape and greenery provision. The use of solar responsive façades for shading and shielding sunlight with a web–based smart system (BIM-enabled intelligent building management system, iBMS) to control and monitor the climate-response, passive and active building system is the key innovative and environmental elements of the project.

The 3D scanning and 5D BIM (Revit) also assists the project team and client to make early and quick decisions in the choice of an effective building structural system and resolve most of the conflict in advance before the construction. The project was successfully completed and obtained different local and overseas building and design awards in architectural aspects and substantiality engineering.

VII. Contribution to the Economy

The concept of sustainable engineering creates the opportunities to significantly reduce the use of natural resources, minimize waste generation and overloading of dumping sites, and mitigates noise, air and water pollution to the community.

Notwithstanding the benefit to the environment, sustainable engineering also creates job opportunities for different sectors including IT, light and heavy industry, logistics and facilities management. Most importantly, sustainable engineering provide many major benefits to the industry and the economy as compared with traditional building and infrastructure construction practice. See Fig. 2.

Fig. 2 Benefits of sustainable engineering to the economy

VIII. Conclusion

This paper has explored some of the key elements and experience sharing for the synergy of innovation and development of sustainable engineering technology and environment assessment tools which validate the achievement of high level sustainable building construction. The key factor to success is still relying on the collaboration of public and private sectors to contribute more in the innovation, development and adoption of the new technology. To meet the target of zero carbon emission is not a slogan; it is however required by different stakeholders in the industry and community to contribute their parts more intensively. Government promotion and support create the incentive to attract clients to pay more attention and willingness to adopt new technology in suitability engineering in their projects. Architecture/Engineering (A/E) specialists involve more resources in research and development of innovation and technology and provide higher levels of training in technology aspects to supply sufficient highly skilled specialists to implement the suitable project. Building contractors should deploy more resources in construction and manufacturing technology in line with the development of Architecture/Engineering (A/E) specialist technology development to achieve a win-win situation.

With the global trend and concern of climate change and the rapid development of innovative technology in BIM, DfMA and MiC in the industry with effective and successful outcomes in energy, waste and carbon emission reductions, we could see more and more intelligent and sustainable buildings being completed with effective time and cost achievement in the coming future.

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