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ORIGINAL PAPER

The outlook of building information modeling for sustainable development

Heap-Yih Chong[1] · Xiangyu Wang[1,2]

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Abstract As human needs evolve, information technologies and natural environments require a wider perspective of sustainable development, especially when examining the built environment that impacts the central of social-ecological systems. The objectives of the paper are (a) to review the status and development of building information modeling (BIM) in regards to the sustainable development in the built environment, and (b) to develop a future outlook framework that promotes BIM in sustainable development. Seven areas of sustainability were classified to analyze forty-four BIM guidelines and standards. This review examines the use of BIM in sustainable development, focusing primarily on certain areas of sustainability, such as project development, design, and construction. The developed framework describes the need for collaboration with the multiple disciplines for the future adoption and use of BIM for the sustainable development. It also considers the integration between "BIM and green assessment criteria"; and "BIM and renewable energy" to address the shortcomings of the standards and guidelines.

Keywords Review · BIM · Sustainable development · Technology · Outlook · Framework · Built environment

✉ Heap-Yih Chong
heap-yih.chong@curtin.edu.au

[1] School of Built Environment, Perth, WA 6845, Australia

[2] Department of Housing and Interior Design, Kyung Hee University, Seoul, Korea

Introduction

The concept of sustainable development is rapidly evolving to embrace the ongoing relationship among social, economy, and natural systems. Innovations in science and technology play a critical role to supporting a transition toward the sustainable development, especially for cleaner productions and operational processes (Kranvanja et al. Kravanja et al. 2015). Built environment has impacted the center of social–ecological systems. It refers to any human-made structures or surroundings for supporting the society and economy. When implementing sustainable practices in the built environment, it is important to engage construction stakeholders (Petri et al. 2015). Building information modeling (BIM) is one of a sustainable technology that can be used to create and monitor a project's digital information throughout its lifecycle. BIM technology has been receiving a tremendous amount of attention from the academia and industry, and offers the potential to transform the conventional project delivery approach (Eastman et al. 2011). BIM is a coordinated, and its consistent data store offers a collaborative working platform for all project stakeholders (Rogers et al. 2015). This innovative approach is able to improve the unproductive and fragmented practice that is currently used in the built environment. Using BIM technologies allows all parties to have the same goal and knowledge into the project in advance from different dimensional models, namely, three-dimensional model (3D), time-related model (4D), cost-related model (5D), and facility management-related model (6D), which are largely contributed by the BIM's virtual and geometry information (Lopez et al. 2015). The applications and uses of BIM allow for sustainable approaches to improve performance (Chong et al. 2014) throughout different stages of the project lifecycle (Wong and Fan 2013).

Previous studies mainly focused on the technological aspects of BIM that developed new and improved BIM applications and uses for the architecture, engineering, and construction (AEC) aspects (Wang and Chong 2015) in buildings or infrastructures (Shou et al. 2015). Although certain sustainability concepts and improvements have been mentioned part and parcel from the previous studies, no prior BIM-related research or review has emphasized on the sustainable development for the entire built environment from a holistic perspective. Therefore, the objectives of the paper are (a) to review the status and development of BIM for the sustainable development in the built environment, and (b) to develop a future outlook framework to promote BIM's use in sustainable development. The review approach adopted a neutral and established perspective on the development of BIM, which all BIM guidelines and standards from different countries were reviewed. This approach was selected so as to provide a clear understanding on the actual practice of BIM in the built environment. Subsequently, the future outlook framework has been developed to address the gaps from the review and also to promote the integrative approach for sustainability practices.

The findings will strengthen the existing systems and policies, and provide important insights into promoting a sustainable built environment through the use of BIM technology. The review approach and analysis method are generalizable for other sustainability technologies in different sectors and industries.

Review approach

BIM is an evolving technology. While it has been well developed and received, it has yet to have comprehensive policies and regulations to popularize the technology (Bossink 2015), especially from the sustainable development perspective. Therefore, the neutral review approach was adopted, where all the standards and guidelines in relation of BIM were reviewed to determine the actual implementation of BIM in contributing into the sustainable development. It was a different approach from reviewing journal or conference articles because the sources would cover a wider view on BIM status and development across different disciplines and sectors in the built environment. The standards and guidelines were selected based on the popularity and references cited in academic publications and industrial magazines/reports. Most of them were derived from developed countries that have been using BIM technologies for several decades (Eastman et al. 2011). These sources would be a good and reliable reference to examine for the sustainable development in the built environment.

Subsequently, there is a need to organize sustainability areas according to the built environment working culture. The latest Royal Institute of British Architects (RIBA)'s Plan of Work 2013 was referred for the organization of the sustainability areas. It is because the plan includes many new activities (including BIM) into the project lifecycle (Bordass and Leaman 2014). Consequently, the related sustainability areas were formulated and modified based on the idea derived from the stages of work in the project lifecycle. Seven (7) sustainability areas were classified according to a number of aspects throughout the project lifecycle, namely,

- *Development*—this area describes to planning and development of the project including the required project delivery approaches or procurement systems. BIM can contribute effective and efficient processes in the project planning and development (Gibbs et al. 2015). This process reduces reworks and unnecessary wastes from re-planning and re-development.
- *Design*—this area describes the design of the project by all design teams, namely, architects and engineers. BIM will improve design and coordination among the design teams for a more practical and constructability of the project (Singh et al. 2011).
- *Construction*—this area describes the construction process of the project. BIM can prepare an early visualization or forecast on time, cost, and quality in a 3D environment (Wang et al. 2014). It will avoid errors in construction processes and improve the constructability or methods used in the project (Wang et al. 2016).
- *Materials*—this area describes the use of the materials and methods for the project. BIM can encourage and test new materials from the virtual 3D environment (Kim et al. 2015). It will improve the project life-span and performance.
- *Energy consumption*—this area describes the related tools and techniques in operating the project. BIM can perform energy simulation of heating, ventilation, air conditioning, and lighting as required in the project (Ahn et al. 2014). It will reduce the energy and power use in a project.
- *Maintenance*—this area describes the maintenance of a project. BIM can provide a centralized and integrated facility management from the virtual environment (Chong et al. 2014). It can forecast and schedule the maintenance needs efficiently. This would help in providing a transparent platform for facilitating informed decision making in facility management (Reza et al. 2014).
- *Demolition*—this area describes the required refurbishment or demolition at the end of the project life-span.

BIM can simulate every element in the project with the required specification and dimensions (Yun et al. 2014). It will support in selecting the right method for demolition or refurbishment.

Findings

Forty-four BIM standards and guidelines were collected from nine countries to review the status and development of BIM for the sustainable development. They were analyzed as per the categorized sustainability areas as shown in Table 1.

Most of the standards and guidelines were derived from United States of America, followed by Australia and United Kingdom. They were developed by universities, government sectors, and non-governmental organizations for the industry use. The most cited and popular BIM standard was National BIM Standard, which was published by National Institute of Building Science and buildingSMART alliance in United States of America.

The qualitative data were converted to quantitative data based on the number of appearance in the review as shown in Table 2. A total of one hundred forty-two sustainability areas were covered and repeated from the standards and guidelines. The design area had the largest number of appearances and recorded forty-two of them. It was followed by the areas of development and construction, which were thirty-nine and thirty-one. The areas of maintenance, materials, and energy consumptions received only sixteen, eight, and six, respectively. Surprisingly, none of the standards and guidelines mentioned about the sustainability area of demolition.

The results show an interesting finding on the current practice of BIM in the built environment, which was focused on the development and design aspects of the guidelines and standards. It has had a significant different compared to the critical review on articles in relation to BIM that was carried out recently by Volk et al. (2014), which most of the articles were identified and focused on energy analysis, lifecycle assessment, sustainability, and retrofit/refurbishment. As the guidelines and standards have been developed for the current need and practice in the industry, this comparison indicates that the current practice for sustainability has not covered for the research findings in those areas as published by the journal articles. This is probably due to the lack of awareness or verification on their potential uses in the industry. This different perspective will provide a good point-of-reference when developing the future outlook framework.

From a holistic perspective, most of the standards and guidelines were focused on the areas of development, design, construction, and maintenance. This is important as these areas serve as the foundation in the preliminary stage for effective adoption and use of BIM technology in the project. These standards and guidelines will facilitate the practice and coordination of BIM among the stakeholders and designers in the collaborative platform. These sustainable practices will contribute toward improved performance and avoidance of unnecessary waste throughout these processes, as stakeholders can make informed decisions by accessing BIM model data. As a result, it could prevent reworks and errors occurred, and indirectly contribute to the sustainable development in the built environment.

Apart from that, other sustainability areas would have a greater and direct impact and influence toward the sustainable development, namely, energy consumption, materials, and demolition. However, in the current BIM standards and guidelines, there are only limited coverage in these areas. The industry should use certain BIM applications and work with the green materials and efficient energy consumptions within buildings or infrastructures to better protect the environment and save on energy use (Yadollahi et al. 2014). BIM can also contribute toward the demolition area as the practice of demolition is rather complicated, and a virtual simulation would help in planning and decision making before the actual demolition. It would provide a fast and accurate waste estimation for demolition projects, and subsequently, it could also optimize energy efficiency of the demolition process (Cheng and Ma 2012). These areas need to be considered in the development of the future outlook framework.

Discussions

BIM has contributed toward certain areas of the sustainable development in the built environment. However, a lot of work need to done to achieve effective outcomes for the categorized sustainability areas. For instance, the green assessments can be referred to strengthen the findings of the review. Some of the recognized and popular indexes are Leadership in Energy and Environmental Design (U.S. Green Building Council Australia 2016), Building Research Establishment Environmental Assessment Methodology (BREEAM 2016), Green Star (Green Building Council Australia 2016), and Green Building Index (GBI Malaysia 2016). Yet, the current practice heavily focuses on construction aspects for green buildings (Chen and Hong 2015). New guidelines and practical tools are needed to support and define the requirements and steps involved for BIM to achieve and fulfill the certification assessment. Particularly, the indexes should be integrated with the sustainability areas

Table 1 BIM guidelines/standards and related sustainability areas

Country	Affected sustainability areas	Organization	BIM guidelines/standards	Description	Reference
Australia	Development, design, construction, materials, maintenance	Sustainable Built Environment National Research Centre	National BIM guidelines and case studies for infrastructure	It is to develop National BIM guidelines for the use in infrastructure projects	SBEnrc (2015)
	Development, design, construction, materials, maintenance	NATSPEC	NATSPEC National BIM guide	It is to clarify BIM requirements for all stakeholders in construction projects to form a nationally consistent view	NATSPEC (2011)
	Development, design, construction, materials, energies consumption, maintenance	Australia Mechanical Contractors' Association	BIM-MEP^{AUS} Practice	It is to provide effective take-up and use of BIM in mechanical, electrical, and plumbing within Australia	AMCA (2011)
	Development, design, construction	Cooperative Research Centre	National guidelines and case studies for digital modeling	It is to assist in and promote the adoption and implementation of BIM technologies in the Australian building and construction industry	CRC (2009)
America	Design	Massachusetts Institute of Technology Department of Facilities	MIT CAD & BIM guidelines	It is to promote the development and use of electronic drawings and models	CPEC (2011)
	Development, design, construction	Georgia Tech Facilities Management	Georgia Tech BIM requirements & guidelines for architects, engineers and contractors	It is to explain the importance of each requirement on a per-project basis for all stakeholders	GTFM (2011)
	Design, construction	Indiana University Architect's Office and Engineering Services	BIM guidelines & standards for architects, engineers, and contractors	It is to explain the standards for architects, engineers and contractors in BIM environment.	AOES (2012)
	Design, construction	University of Washington Capital Projects Office	Attachment G—University of Washington CAD and BIM standards	It is about standards for architects or engineers developed project drawings for compliance review	CPO (2012)
	Development, design, construction	University of Southern California Facilities Management Services	BIM guidelines	It is about the design and construction scope of work and deliverables based on a Design Bid Build form of Contract	FMS (2012)
	Development, design, construction, maintenance	Los Angeles Community College District	BIM standard	It is about standards for design–build projects to define a process and establish requirements, procedures and protocol for the utilization of BIM in the various stages of our design–build projects	LACCD (2011)
	Design, construction	San Diego Community College District	BIM standards for architects, engineers & contractors	It is about standards for architects, engineers and contractors to improve the quality of the design solutions and optimize the exchange of information between parties	SDCCD (2012)

Table 1 continued

Country	Affected sustainability areas	Organization	BIM guidelines/standards	Description	Reference
	Design, energies consumption, maintenance	The Pennsylvania State University	BIM planning guide for facility owners	It is about a guide for facility owners who operate and maintain facilities.	PSU (2012)
	Development, design, construction, maintenance	College of the Desert	BIM guide	It is for the design, construction, and management for an overall BIM project workflow	CoD (2011)
	Development, design, construction, materials, energies consumption, maintenance	National Institute of Building Science, buildingSMART alliance	National BIM standard version 2 (version 3 will be released in April, 2015)	It is about building information exchanges to support critical business contexts using standard semantics and ontologies	NIBS (2012)
	Development, design	United States General Services Administration	National 3D–4D BIM program	It is about the guide for BIM practices in designing of new construction and major modernization projects	GSA (2007)
	Development, design, construction, materials, energies consumption, maintenance	United States General Services Administration	GSA National 3D–4D—BIM Program	It is to explain the eight BIM guide series, i.e., 3D–4D—BIM overview; spatial program validation; 3D laser scanning; 4D phasing; energy performance and operations; circulation and security validation; building elements; and facility management	GSA (2012)
	Development, design	American Institute of Architects	E202-2008 BIM protocol	It is about the protocols, expected levels of development, authorized uses, and responsibility of BIM on this project	AIA (2008)
	Construction	Associated General Contractors of America	The contractor's guide to BIM	It is an entry level to introduce BIM and provide an outline of the "how-to" for getting started	AGC (2009)
	Development	United States Air Force Centre for Engineering and the Environment Capital Investment Management	"ATTACHMENT F"—BIM requirement	It is about the requirement for design–build/firm fixed-price contract	AFCEECIM (2012)
	Development, design, construction, maintenance	United States Army Corps of Engineers	Roadmap for lifecycle BIM	It is about the use of BIM for civil works and military construction business processes for industry partners and software vendors	USACE (2012)
	Development, design, construction	United States Veterans Affairs	VA BIM guide	It is about the design and construction for the architects, engineers, other consultants, and contractors	USVA (2010)
	Development, design, construction, materials, energies consumption, maintenance	New York City Department of Design + Construction	BIM guidelines	It is a rather compressive guide to review the ways in which the BIM may facilitate their ongoing building operation and maintenance protocols from the design and construction of the project	DDC (2012)
	Development, design, construction	New York School Construction Authority	BIM guidelines and standards for architects and engineers	It is about the guidelines and standards for architects and engineers in using BIM and its software in a coordinated contract environment.	NYSCA (2012)

Table 1 continued

Country	Affected sustainability areas	Organization	BIM guidelines/standards	Description	Reference
	Development, design, construction, materials, maintenance	City of San Antonio Capital Improvements Management Services	BIM development criteria and standards for design & construction projects (aka "CoSA BIM Standards")	It is to define a process and establish requirements, procedures, and protocol for using BIM in the various stages in the design and construction building projects and also to more efficiently manage, maintain, and renovate the facility for the lifecycle of the building	CIMS (2011)
	Development, design, construction	The Port Authority of NY & NJ Engineering Department	EAD (E/A Design Division) BIM standard manual	It is to explain the processes and procedures required for the preparation and submission of BIM Models	PANY & NJED (2012)
	Development, design, construction	State of Ohio Facilities Construction Commission	BIM protocol	It is to explain a common methodology for communicating the level of details or minimum expectations and data required in the model	OFCC (2012)
	Development, design,	State of Texas, Texas Facilities Commission	Professional service provider guidelines and standards	It is about the guidelines and standards for architectural and engineering process in BIM models.	TFC (2010)
	Development, design	State of Wisconsin Department of Administration, Division of State Facilities	DSF BIM guidelines & standards for architects and engineers	It is to explain the guidelines and standards for architects and engineers in BIM models	(DOA/DSF 2009)
	Development, design	Georgia State Financing and Investment Commission	GSFIC BIM guide series 01: model analysis and validation	It is to aid architects and engineers to design and construction BIM projects	GSFIC (2013)
Denmark	Development, design	Erhvervsstyrelsen (National Agency for Enterprise and Construction)	Det Digitale Byggeri (digital construction)	It consists of four components: 3D CAD manual, 3D working method, project agreement and layer, and object structures	NAEC (2007)
Finland	Development, design	BuildingSMART Finland	Yleiset tietomallivaatimukset	The guidelines mainly focuses on architecture and engineer design	BuildingSmart Finland (2012a)
	Development, design, construction, materials, energies consumption, maintenance	BuildingSMART Finland	COBIM common BIM requirements	It consists of 13 sections for all disciplines for BIM models and requirements throughout the project lifecycle	BuildingSmart Finland (2012b)
Norway	Development, design	Boligprodusentene	BoligBIM	It is to provide aid for those who perform the project planning for residential dwellings in BIM models	NHBA (2011)
	Development, design, construction	Statsbygg	Statsbygg BIM manual	It is a 'full-scale IFC test' documenting experiences gained on a collaborative project	Statsbygg (2012)
Netherlands	Development, design, construction, maintenance	Rijksgebouwendienst (Ministry of the Interior and Kingdom Relations)	Rgd BIM standard	It is a rather comprehensive BIM framework consisting of seventeen orthogonal dimensions that describe in general	MIKR (2012)

Table 1 continued

Country	Affected sustainability areas	Organization	BIM guidelines/standards	Description	Reference
United Kingdom	Development, design, construction	British Standards Institution	BS 1192:2007 Collaborative production of architectural, engineering and construction information. Code of practice	It is about methodology for managing the production, distribution of the construction information	BSI (2007)
	Development, design, construction	British Standards Institution	BIP 2207 Building information management. A standard framework and guide to BS 1192	It explains in detail the processes and procedures for having quality architectural, engineering, and construction information	BSI (2010)
	Development, design	AEC (UK)	BIM standard for AEC industry in UK	It is to explain a unified BIM standard for the structuring of their BIM data for designers	AEC UK (2011)
	Development, design	AEC (UK)	AEC (UK)BIM protocol	It is to provide standards for practical and efficient use of BIM, particularly at the design stages of a project	(AEC UK 2012)
	Development, design, construction, maintenance	Construction Industry Council	Best practice guide for professional indemnity insurance when using BIM and, outline scope of services	It is to support the construction industry's take-up of level 2 BIM, and to explain key areas of risk	CIC (2013)
	Development, design, construction, maintenance	Specialist Engineering Contractors' BIM Academy at the University of Northumbria. National Specialist Contractors' Council	First steps to BIM competence: a guide for specialist contractors	It is to acquaint firms with the steps they need to take to become comfortable using Level 2 BIM	SEC (2013)
Singapore	Development, design, construction	Building and Construction Authority	Singapore BIM Guide	It is to outline the roles and responsibilities of project members when implementing BIM at different stages of a project	BCA (2012)
	Development, design	CORENET e-submission system	CORENET BIM e-submission guidelines	It is also cover architectural, structural, and MEP guidelines	CORENET (2011)
Hong Kong	Development, design, construction, maintenance	The Hong Kong Institute of Building Information Modeling	BIM project specification	It is to define the scope of work for a BIM process, the responsibilities of the project participants, and the deliverables	HKIBIM (2011)

of materials, energy consumption, and demolition from the BIM perspective. This approach is feasible as the green assessment criteria are rather generic and fit the required sustainable improvements in the built environment. These sustainability areas can be achieved through the simulations conducted using specialized BIM software during the design stage of the project. Doing this will allow for the production of energy efficient, healthier, and more environmentally conscious buildings.

BIM should also incorporate more sustainability functions when dealing with climate changes and greenhouse effects. BIM can simulate the energy and water usage within an asset. BIM allows its user to design the optimum consumption of the energy and water from different sources of energy or watering systems. For instance, the clean or renewable energy should be considered in the asset, which it will create a tremendous sustainability impact to the built environment through its policy (Chong and Lam 2013) or technology (Sakmani et al. 2013). The integration of the clean or renewable energy with BIM is a new concept. It will create various opportunities to both industry and academia. From a conceptual point of view, it can optimize the energy use and carbon emissions from buildings or infrastructures, and subsequently it can extend

Table 2 Converted quantitative results

Items	Sustainability areas	Numbers of coverage
1	Development	39
2	Design	42
3	Construction	31
4	Materials	8
5	Energies consumption	6
6	Maintenance	16
7	Demolition	0

to a community, a town, or even a city. It will not only save the energy use, but also the additional energy can be reserved or even generated for other use in the area (for example, solar panels). This will contribute significantly to the natural environment.

Overall, the paper highlights that the current standards and guidelines have contributed on certain sustainability areas in the built environment. The needs for the integrations between (a) BIM and green assessment criteria, and (b) BIM and renewable energy are the important implications of the review. The integrations will address the shortcomings of coverage on the sustainability areas.

Future outlook framework

The integrations between (a) BIM and green assessment criteria, and (b) BIM and renewable energy should collaborate with multiple disciplines as to support the effective adoption and use of BIM for the sustainable development. It is because the norm practice of sustainability technologies is to primarily focus on an individual approach within the single discipline, which will create barriers to the market entry (Hoppmann et al., 2013). Consequently, some recent studies have begun to look into the integrative approach in addressing the sustainability issues through their policies (Teschner et al. 2012) or deployment strategies (Erzurumlu and Erzurumlu 2013). As a result, the framework development should consider the integrative approach from various disciplines or sectors. Yet, the multidisciplinary integrative approach is very challenging as it requires a high level of integration and knowledge from various disciplines.

Therefore, an attempt to integrate different disciplines is initiated in this paper. First, it needs to identify all related disciplines. The identification of the disciplines is rather a subjective process, but two arbitrary rules have been adopted in the process namely, (a) the disciplines need to uphold current and future BIM development that will integrate with other advanced technologies to contribute toward sustainable development and overall project performance (Wang and Chong 2015), and (b) the disciplines should be based on an embracing holism philosophy to accommodate the increased complex characteristics and policies in the planning, design, construction, and operation of the built environment (Lizarralde et al. 2014). After the detailed consideration, six generic disciplines have been identified such as, law, management, information communication and technology (ICT), engineering, energy, and health science.

Next, the identified disciplines need to connect with the seven sustainability areas in the built environment as shown in Table 3. This is to promote a collaborative working environment of BIM that can support the integration and enhance working relationships among the disciplines. Some practical examples have been proposed to explain clearly the potential areas of the integration for improving sustainable development in the built environment. The law and management disciplines are perceived as the fundamental processes for all the sustainability areas.

The development of the future outlook framework is focused on promoting BIM as a way of addressing sustainable development in the built environment. The development process needs to consider the findings and gaps as identified from the review and also to correlate with the multiple disciplines as highlighted. As a result, the framework (Fig. 1) was developed with the intention of describing and accommodating the concerns above into a simplified manner. It explains the need for developing more standards and guidelines for the sustainability areas of materials, energy, and demolition. Meanwhile, new functions of BIM should be explored in future practices so as to incorporate the built environment with green assessment criteria and renewable energy. All these processes should work under a collaborative platform with the related disciplines to tackle the sustainable development. It can start from a single asset either in building or infrastructure, and extend it to a bigger community area.

In summary, this paper renders three main contributions. First, the review has uncovered certain sustainability areas that require serious attention and development by the universities, governments, or non-government organizations. Second, the paper has proposed two new integrations for BIM with green assessment criteria and renewable energy. Lastly, the framework has highlighted the integrative approach with different disciplines in promoting for sustainability practices for BIM in the built environment.

Conclusions

This study has provided a review on the status and development of BIM for sustainable development in the built environment based on forty-four BIM guidelines and

Table 3 Integrating sustainability areas with different disciplines

Sustainability areas	BIM integrating disciplines	Remarks to sustainability
Development	Law, management,	E.g., National Acts and Regulations, proper planning and selection of site, etc
Design	Law, management, ICT, energy, health science	E.g., green building, paper-less contract documents, collaborative working relationship, designing to co-exist with natural systems, considering human comfort and living styles, etc
Construction	Law, management, ICT, engineering, energy	E.g., sustainable construction, green construction technologies, green waste management, high productivity, etc
Materials	Law, management, ICT, engineering, energy, materials, heath science	E.g., prefabrication technologies, green materials and products, etc
Energy consumption	Law, management, ICT, engineering, energy, health science	E.g., renewable energies, living with natural systems, human comfort and health, etc
Maintenance	Law, management, ICT, energy, health science	E.g., effective preventive and corrective maintenance, automation or sensor applications, etc
Demolition	Law, management, ICT, engineering, energy	E.g., environmental friendly policies and technologies, recycling, refurbishment, etc

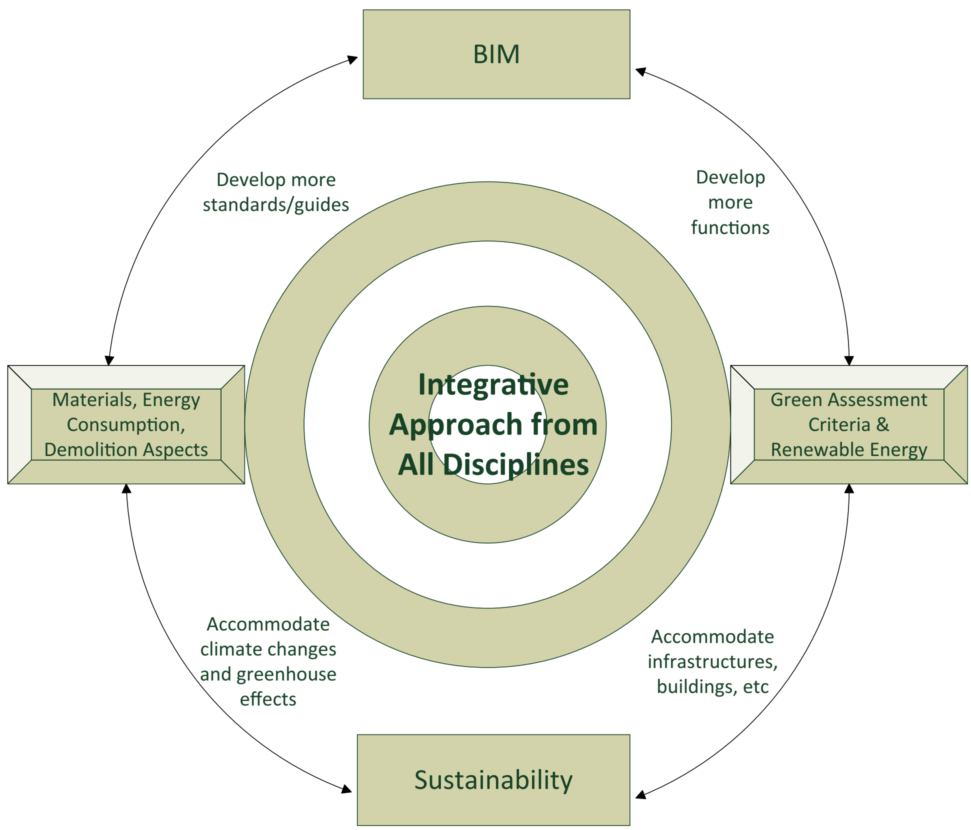

Fig. 1 The future outlook framework in the built environment

standards. The review has classified the guidelines and standards into seven sustainability areas. The results show that the sustainability areas of development, design, and construction are the main focus areas in BIM. This paper has developed a future outlook framework in promoting BIM for the sustainable development. The framework has considered the gaps from the review on the sustainability areas of materials, energy, and demolition and has also incorporated the integrative approach for sustainability practices for BIM with green assessment criteria and renewable energy under a multidisciplinary platform.

Certain limitations need to be considered in the review. The review sources have not adopted other BIM standards or guidelines that are published by vendors as to preserve the neutral position for the data analysis. Some BIM standards or guidelines may also not be included in the review, especially from the developing countries. The limitations serve as reminders that this review is not definitive as some useful information may change the results of the review. Nevertheless, the review has successfully achieved the objectives and rendered insightful references in promoting the sustainability practices for BIM in the built environment. Certain areas of the review approach and the framework can be generalized and referred by other sustainability technologies in different sectors.

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