Application of Structural Building Information Modeling (S-BIM) for Sustainable Buildings Design and Waste Reduction: A Review

Usman Aminu Umar1,a, Nasir Shafiq1,b, Amirhossein Malakahmad1,c, Muhd Fadhil Nuruddin1,d, Syed Ahmad Farhan1,e, Ibrahim Umar Salihi1,f
1Department of Civil and Environmental Engineering, Faculty of Engineering, Universiti Teknologi Petronas 32610, Bandar Seri Iskandar, Perak, Malaysia.
E-mail: ausmanaumar@yahoo.com, bnasirshafiq@petronas.com.my, camar’hossein@petronas.com.my, dfadhilnuruddin@petronas.com.my, esyfarisk@gmail.com, fsalihi37@yahoo.com

Abstract
Strategies of sustainable reasoning are in many ways historical. When buildings from some of the indigenous cultures are examined, it can be easily observed that they were highly competent at adapting the location and materials of the structures to the climate. As time passes and civilizations grew static, buildings took on different values. Structural Building Information Modeling (S-BIM) enables structural engineers and designers to develop structural models for steel, concrete and timber buildings with flexibility; examine engineering alternatives; create smarter well-informed design decisions; and anticipate costs and overall performance. By using Building Information Modeling (BIM), pre-requisites for drawings are reduced. Technical details are regularly updated and easily obtained from the model, which provide designers the platform to resolve design issues and allow team members access to view the plans. BIM stores data for all aspects of the building, which include structural; architectural; mechanical, electrical and plumbing (MEP); and landscape data before and during post-construction phases. The paper reviews advantages of S-BIM application for sustainable building design and waste reduction as acknowledged by experts from the construction industry and recommends anticipated outcomes for improvement to the Architecture, Engineering and Construction (AEC) industry.

Keywords: Building Information Modeling, S-BIM, Sustainable Building Design, Waste Reduction, Construction Waste.

Introduction
Application of computers to optimize building processes is continuous [1]. Building Information Modeling (BIM) is a useful platform for optimization of building operations as it stores important structural data. As implied, BIM is applicable for all stages during building activities. The building process consists of numerous players and professions. For instance, the design phase involves plumbing, structural and energy designs. In other words, BIM signifies the integrated process of constructing, engineering, designing and sustaining a building based on information models. Therefore, the model can act as a standard workplace to various parties of the building process [2]. Among the aims of applying BIM is to acquire greater collaboration between participants and a continuous workflow that often emerge more simultaneously.

Furthermore, BIM aims to reduce repetitive re-entering of data, which can be accomplished considering all details applicable to the building are collected in a general model to minimize construction and design issues. Several construction disciplines usually contain inconsistent models such as the model with structural components and electrical and mechanical systems with the model for heating and ventilation systems. The built environment is identified by policy makers and stakeholders as having substantial duties to play in minimizing carbon emissions and construction waste for them to attain sustainable development [3, 4]. Evaluation and certification techniques are continually acclaimed as essential strategies by which to realize it. Nevertheless, strength of the applications at engendering the principle concepts of sustainability as recommended by experts is invalidated as a result of failure to cope with fundamental industry-scale organizational challenges and a lack of ideal knowledge of what sustainability truly is and implies to the construction sector. However, the heavily fragmented construction and design practice, which comprises different stakeholders with separate strategies and particular project aims, are impacted by various professional operational codes that create interdisciplinary work at initial phases of design [5].

In the construction sector, waste could occur through any activity conducted by one or more of these; designer, manufacturer, construction activity and client. Gavilan et al. [6] and Craven et al. [7] explained the primary factors behind waste material generation, which, among others, include errors in contract documents, modifications to design, purchasing error, accident, lack of site control, absence of waste management, damage during transportation and wastes from cutting materials to length. Then again, Chen et al. [8] stress that construction waste continues beyond control due to three elements: construction organizations unwilling to embrace low-waste approach because it is expensive to employ; design coordination provides a significant effect of waste generation; and on-site construction waste. In the management and distribution of materials from the producer or supplier to site, possibilities of loss or damages to materials could not be prevented. As a result, the adversarial culture related to conventional building encourages self-interest and there is a need for voluntary and institutional systems to guarantee conformity for sustainability. The present customs let stakeholders formulate judgments that indicate their benefit and choose the method that offers the ideal result for them to
fulfill organizational objectives instead of building performance within the environmental position. With existing laws imposing minimal requirements for sustainability, they are inevitably recognized by project teams as an alternative to the primary aim of completing projects on-time and within budget. The present study aims to review the application of Structural Building Information Modeling (S-BIM) for sustainable building design and waste reduction.

Research Background and Motivation

Structural Building Information Modeling (S-BIM)

BIM as a concept suggested by Coenders [2] outlines the foundation for digital, virtual and computational models. It contains a lot of data such as input for computation, source for drawing, price estimations, visualization and time schedules. Among the information are three-dimensional (3D) models and other additional elements of the information such as text and diagrams. The information contained in the model is constantly developed from various players from the building segment. Therefore, the model is applicable to the whole process, from the planning stage to demolition after the operation stage. Theoretically, BIM allows a continuous workflow in which the required information is continuously obtainable for all participants, which minimizes the necessity to reproduce information models. For example, the architectural model could be based on the model by the landscape architect, energy model and electrical model, while the structural model could be dependent on the architectural model. Hence, the information developed by the architect form the fundamental based on the S-BIM design. The key expatriates in the S-BIM design stage are architects, engineers and draughtsmen. The architects typically control the conceptual design stage while the engineers and draughtsmen control the detailed design stage. An effective structural design stage depends on the teamwork and information exchange amongst professionals involved. Ordinarily, the work carried out by the three players arise in three proportional division ways staggered in time, starting with the architect and finishing with the draughtsman. An object or component can have details regarding the kind of element, material properties, sectional properties as well as the function of the component within the structure. Numerous existing architectural solutions are incredibly complicated that structural components can only be effectively placed and developed in a 3D environment, as the structural model is produced within the computer model prior to any physical material involvement, leading to time savings, cost and error reduction.

Literature on the incorporation of sustainability tools with BIM has demonstrated the advancement in evaluation of development and performance as a result of extensive and effective data removal that lowers the time, effort and cost of assessment. Multidisciplinary sustainable design alternatives created at the design phase allow comparatively quick and economical enhancements as compared to modifications made during and after construction, along with a decline in human error by applying consistent and authorized information.

For the successful cooperation among various engineering professions, it is important to have the infrastructure data efficiently structured. BIM is recognized for its design and documentation capabilities, which permits the storage of valuable computable information that allows work coordination and consistency among end users [9]. Structural engineers presently use BIM mainly to produce drawings and for coordination. The effective use of BIM could entirely transform the approach by which infrastructure projects are constructed, performed and maintained [9]. The involvement of numerous infrastructure projects demands strong multidisciplinary cooperation, which can be realized with BIM project information that is accessible and actionable through each stage of the infrastructure. During the start of the construction phase, it is feasible to visualize the project through most of the construction process such as scheduling (4D) and costs (5D) [9]. The forms of structural information that can be integrated into the S-BIM model are, among others, element properties and types. Applying all this information, a structural analysis model can be constructed with boundary conditions, loads and other details that can be imported into a structural analysis tool as shown in Figure 1. As soon as the model is adjusted with all the element attributes, then the analysis for structural safety can be executed. Based on the outcomes, design and construction documents can be modified with the updated details.

Figure 1: Conceptual S-BIM model during design stage

Conceptual S-BIM Model for Sustainable Building Design and Waste Reduction

BIM and sustainability are quite recent ideas in the Architecture, Engineering and Construction (AEC) sectors; hence understanding of the possible working relationships has only just started. Krygiel and Nies [10] proposed new developments in BIM such as enhancements in application interoperability and incorporation of a carbon accounting tracker and climatic condition information to improve the functionality with sustainability. Azhar [11] highlighted the application of BIM for determination of building orientation, assessment of skin options, and execution of daylight analyses on site during the design stage, to enhance sustainability. Holness [12] noted that due to the development in sustainability towards net-zero-energy buildings and carbon emission minimization, designers have to evaluate the building as a wholly integrated dynamic design and construction process. Stadel et al. [13] proposed the application of BIM functionality with life-cycle cost analysis
(LCA) to carry out carbon accounting by exporting the material schedule for the building and utilizing BIM application plug-ins to determine operational energy use and carbon emissions.

The American Institute of Architects (AIA) defined sustainability as the “ability of society to continue functioning into the future without being forced into decline through exhaustion or overloading of the key resources on which that system depends on” [14] while Hill and Bowen [15] describe it as “a means of building a healthy built environment by means of resource-efficient and ecologically-based principles”. There is no general opinion about the meaning of sustainable building or infrastructural construction, although the frequent definition of sustainability in the construction sector is the “provision of buildings designed to employ less virgin material and energy, and generate less carbon dioxide and waste; techniques and methods of design that promote a sustainable model of livelihood through the entire built environment in accordance with the principal of triple-bottom-line strategy” [13]. A model can transform from static concepts of building effectiveness into the regenerative contributions the built environment makes to the social, ecological and economic well-being of the area in which it performs. To accomplish this, traditional understanding among various stakeholders is needed: a shift from a remote and static perceptive of building performance with regard to design; and strong exchange of ideas that promotes awareness of the significance of the building lifecycle on occupant existence and business achievement to engage and sustain stakeholder determination [16-18].

Determining the sustainability of buildings is an extremely intricate task considering the broad array and variety of challenges to be tackled. The complication of the process is further increased with the problem of handling carbon emissions and other connected environmental, social and economic problems. Awareness on the challenges that buildings can put on natural systems has grown speedily over the past couple of years, as well as the knowledge on how to design and create sustainable buildings, although such understanding is valueless if not converted towards successful decision-making, whether at the political level, procurement stage or in the construction and design stages. Nevertheless, determining the sustainability of a building remains challenging. Several methods are presently used to evaluate sustainability. For example, the Global Reporting Initiative (GRI) applies indicators for material use, energy consumption, water use, emissions reduction, waste minimization and several other environmental and social issues to determine the ecological footprint [19].

At the moment, in most construction organizations, for the practices of sustainable building and infrastructure design, the conventional Computer Aided Design (CAD) instruments are employed to model buildings. Design details are subsequently entered into a simulation tool to evaluate building or structural performances. Creation of the S-BIM application that incorporates the design model with the simulation tool enables the examination of multi-disciplinary information in a single model, which enhances the assessment and eradicates mistakes of data handling [11]. The intelligent information produced by the BIM model aids the execution of whole-building investigation and simulation of performance and visualization [20], which provide building practitioners with immediate responses to check the design and increase building effectiveness over the lifecycle. Generally, practitioners are able to measure the sustainability performance of design elements such as construction materials, system types, building types, room types and project locations, by exporting data to building simulation software. The standard output from the simulation applications include structural, energy/thermal, lighting/shading, acoustic and value/cost analyses. As the need for BIM is increasingly recognized, more tasks in the building sector are adopting BIM and sustainable design approaches [21] due to the fact that sustainable design is a new measure of perception, design and enterprise according to the acceptance that mankind is a primary element of the global processes [22]. Therefore, the impact on the processes should be more ideal to sustain ourselves, the different species and the planet. Figure 2 demonstrates how BIM is able to identify various errors during the conceptual design phase while Figure 3 elaborates how sustainability can be defined and integrated into S-BIM for sustainable design and environment.

![Figure 2: BIM model during design to reduce design errors](image)

**Figure 2: BIM model during design to reduce design errors**

**Figure 3: Working definition of sustainability for Planning and design [22]**

**Demand of S-BIM Application for Sustainable Design**

It is reported that 40% of worldwide carbon dioxide emissions come from building operations [23]. However, El-Alfy [24] claims that economic, functionality, durability, aesthetics, ecology, health and socio-cultural elements of a building design are altogether impacting the sustainability of the...
building. Sustainability of a building relies upon many inter-related and inter-dependent elements and the elements are influenced by design decisions given by various participants of a construction project [25]. Inter-relations and inter-dependencies that are regarded as imperative for sustainability evaluation demand standard assessment and design information produced by various participants of the project design team. Thus, a collaborative and effective building information system is required to guide the analyses [26]. In conventional non-BIM design workflow, overall performance evaluation of the design is usually performed after completing the architectural design when it is virtually completed [27, 28]. Such performance evaluation contains many independent detailed analyses generated by expert software [29]. Basically, the detailed information is not accessible at the initial design phase but requires substantial explanation by experts [28]. The independent analyses obstruct the holistic understanding of sustainability challenges and offering of alternative sustainable design options [29]. Sustainable building design is a matter of optimization of countless diverse factors of a building as a result of irregular nature of the elements affecting sustainability [25] that produces many issues from early-design sustainability analysis. Initially, information from various participants of the design team must be incorporated and should be obtainable and exploitable to carry out comprehensive computerized sustainability analyses [30, 31]. Secondly, sustainability experts are required for the interpretation of client requirements and project-particular constraints to establish specific sustainability performance criteria. The sustainability professional must understand the various areas of building sustainability and the connections at system-level and can interpret outcomes to support decision-making [32]. Meanwhile, sustainability and environmental issues of the building must be considered even before the conceptual design phase, and the issues should be demonstrated in the conceptual design alternative to effectively attain sustainability. Figure 4 shows how BIM is able to analyze sustainability of a material during the design phase.

![Conceptual S-BIM model](image)

**Figure 4:** Conceptual S-BIM model to determine the sustainability of the material during design stage.

**The Advantages of S-BIM Model**

i. Use of the multi-material S-BIM approach allows the engineering practice to successfully share structural information with other organizations and platforms, thus offering accurate collaboration. Structural advancement and enhancement can be rapidly accomplished as all information is constantly co-existing and in one position, thus enabling the smooth development of structural strategies and thoughts. Any information can be summarized inside the object database, which can be refined to match project needs, such as information from the client and architect.

ii. In order to model numerous designs, the S-BIM solution should be on the ideal perspective platform for the work to be finished as a simple input, while adjustment and control are necessary in the 3D environment. To follow a common drawing platform out of the framework would not be suitable regardless of whether or not it is a well-known solution.

iii. S-BIM can be employed in upstream and downstream projects. Therefore, the model can be forwarded to the principal contractor and then back again to the engineer or client for authorization. All construction drawing data can be saved in one area, thus enabling complete life-cycle assistance and providing real 3D visual communication.

iv. Whole control and removal of errors are achievable as all sketches and information needs in the form of reports are instantly created from the model. Additionally, many consumers would acknowledge that it is faster and simpler to analyze a model rather than looking through thousands of drawings either shown in electronic format or on paper.

v. There is a massive distinction between an actual physical model and an analytical model due to the huge variation in information content, quality and extendibility. By applying object extensions, the S-BIM 3D physical model can be prolonged to a 4D model by incorporating time information inside the object.

**Professionals’ views of material wastage on construction**

It has been witnessed that the construction sector continues to be an important economic area, although the pollution produced by construction activities continuously present a significant obstacle to environmental management [33]. Construction waste has caused serious environmental problems in several significant metropolitan areas [34]. Teo et al. [35] discovered that additional construction materials are frequently procured, which is caused by material wastage at the time of construction. Previous researches have confirmed that waste present relatively greater amount of production cost [35]. Hore et al. [36] cited in Ajayi et al., opined that in every one hundred buildings constructed, there is sufficient waste material to build an additional ten houses. It is therefore obvious that monetary losses from construction material wastage can cause a significant risk to the economic development of a country. Furthermore, there are different views held by researchers with regard to what comprises construction waste. Cheung [37] defined construction waste as the by-product generated and removed from construction, renovation and demolition work areas or sites of building and civil engineering structures. Formoso et al. [38] defined construction waste as virtually any inefficiency that leads to the utilization of equipment, labour, materials or capital in...
larger amounts rather than those regarded in the production of a building. In accordance with Shen et al. [39], building material wastage is defined as the difference between the value of materials shipped and accepted on site and those properly used as specified and accurately measured in the work, after subtracting the cost saving of substituted materials transferred elsewhere, in which unwanted cost and time can be incurred by material wastage.

Formoso et al. [40] noticed that the belief of waste is directly linked to the debris removed from site and disposed in landfills and claims that the major reason for the comparatively narrow view of waste is that it is relatively simple to determine and assess. Although as essential as the concept is from environmental perspectives, it has been criticized since the beginning of industrial engineering. In lean production paradigm, it is viewed as resources that do not increase the value to the final product. Keal [41] further stressed that any material or object that are discarded, intended to be discarded, or are needed to be discarded is waste, subject to a number of regulation requirement. Dania et al. [42] explained that construction and demolition waste is a complex waste stream, comprised of numerous types of materials, which are in the form of building debris, rubble, earth, concrete, steel, timber and mixed site clearance materials, as a result of different construction activities, such as land excavation or formation, civil and building construction site, clearance, demolition activities, road work, and building renovation. In supporting the success of sustainable projects, it is crucial that the necessary sustainable materials and environmental measures are monitored and enforced throughout construction to ensure that the products are fixed using ecological construction methods. The materials employed in a building during both construction and operations can contribute significantly towards the environmental footprint of the building and waste reduction [43, 44].

**Sustainable Waste reduction for cleaner environment**

The importance of waste reduction at the source of production cannot be overemphasized. Although some individual industries have adopted waste minimization techniques, the efforts are quite restricted and do not considerably impact waste quantities for disposal. Presently, there are no legal or fiscal instruments targeted at demanding waste generators to minimize the volume of waste they generate. The idea of “Zero Waste” has been regarded as a long-term commitment towards the proper approach. The particular approach needs fundamental changes in the manner people believe and respond, and inevitably, will need substantial costs to be put in place and the essential support infrastructure.

Sustainable development is an evolution that considers the challenge of prioritizing the environment as the primary attention rather than building whatever is planned and making it into a reality. Among the major subjects of sustainable development is managing waste. Sustainable waste management promotes generation of less waste products, reuse, recycling and recovery of waste generated. Besides the unfavorable impact on the environment as a result of destruction of natural resources, it could raise the volume of waste and pollution if no action to deal with the issue is taken. Several nations, particularly in the European Union (EU), have implemented the waste management hierarchy, which consists of the techniques of waste control such as reduction, re-use, recycling and recovery, in the order of priority as demonstrated in Figure 5. The prime concern is to minimize the volume of waste generated followed by slowing the content material from coming into the waste stream. The next phase is recovery, which consists of composting, recycling and energy recovery. The least preferred alternative for waste management is disposal to landfill or incineration.

**Figure 5: Waste Management Hierarchy**

**Methodology of Using S-BIM Model**

The structural engineering section of BIM is assigned the acronym S-BIM. The architect concentrates on the creative appearance of the structure and the connection involving the design and the environment in all perception. Many architectural models only present surfaces of the structure and do not include details regarding structural components. Architects work with space, mass texture and shapes while engineers work on building objects in the S-BIM [45]. The architectural model is a section of the BIM model that indicates that the building block contents of the architectural and S-BIM models can be quite different, which signifies that the architectural models ultimately constitute the foundation of the S-BIM models. S-BIM contains the necessary information for structural engineers such as loads, load combinations, geometry, boundary conditions, material properties and sectional elements. Therefore, S-BIM can be employed in the structural evaluation as well as design and report production. Furthermore, in the S-BIM model, details regarding the static system, structural elements, strength parameters and others are provided. The features are included by the structural engineer. In an effort to acquire a steady workflow in the structural design stage, the architectural components have to be changed into structural components.

The multi-material part consists of the physical assessment and design details and can be applied to all drawings and details construction. In this regard, the S-BIM approach can
be seen as an aspect in which vast majority of the multi-material structural information is developed and processed to create the specific structure. Architectural models are not involved in the scope, mass, texture and shapes and they do not function with building elements in a similar manner as described in the S-BIM. Nevertheless, the bond involving architectural models and S-BIM is an exceptionally precise method to support the longer term development of a smart integrated model, which needs to constantly be obtainable in the reference models in a similar manner to the External References (XREF) function that is applied to a 2D drawing. The reference models can be 2D details for collaboration with non-BIM application. The model begins to develop at the engineering phase, where conceptual judgments of the structural varieties are designed. It is sometimes believed that the design part is the only absolute real dimensions of the structural components. In reality, it is more than that, since it contains engineering and the value engineering information such as materials used, the relationships as well as the references to the architectural elements. Moreover, load-bearing elements are designed and built into the model. S-BIM is not a major stage during this action but only an additional output that can be created and managed via the physical model. When adjustments happen, they could be produced immediately in the S-BIM model, with virtually all analysis and design results as well as other results updated accordingly as parametric elements can adjust and respond to modification.

The sensors have global positioning systems and thus the locations and IDs of all sensor nodes and the area names are known to the sensors. The sensors are outfitted with powerful antennas so that they can communicate among themselves and to the service station straight using long range communication technologies. The energy consumption of nodes in the network is different to one another as each node will perform different tasks. When a sensor finds that its battery energy level is reduced, it moves back to the service station for battery replacement. The traveling and battery replacement time is short compared to the recharge time. The sensor can approach the sensors in close proximity and induce enough currents on the sensor receiving coils for battery recharge. Sensors query the network for energy information and recharge nodes based on the energy information collected.

Review Findings

Findings of the study show that S-BIM has a variety of features that can be employed to enhance sustainability in building design, construction, operations as well as material waste reduction. Initially, it can be utilized as a decision-making application to decrease the volume of work in assessing numerous design alternatives in the beginning of the design process and conveniently exported to Ecotect or Green Building Studio for energy or delighting assessment [29]. Products like Revit Mechanical, Electrical and Plumbing (MEP) and Integrated Environmental Solutions (IES) virtual environmental enable bi-directional connections among S-BIM and environmental software [29] that could lead to enhanced success towards sustainability standards. Capper et al. recommended that S-BIM can be applied to examine both operational and embodied CO₂ emissions during the life cycle of a project [46] while Sheth et al. indicate that S-BIM is being utilized by industry experts to present the information needed to illustrate conformity with environmental assessment standards, for instance, determining travel distances, information of energy need or solar calculations [47]. As part of the study on Building the Future: Integrating Building Information Modeling and Environmental Assessment Methodologies, Alexander et al. describe S-BIM as a thoroughly collaborative information library model that will save a lot of data in both 2D and 3D as well as element and material requirements. They further show an excellent example of information on particular material and wall components, which could be quickly made and aligned with a sustainability rating or grade, and argue that traditional CAD model can be quite time consuming [48]. While the strength of BIM as stated by Sheth et al. is designed for visualization that can be used to rapidly produce top-quality rendered images for visualization purposes in addition to generating walkthroughs for clients and stakeholders, they further mentioned that the gain here for sustainable buildings is in the visualization of low and zero-carbon-energy applications like solar photovoltaic panels. Numerous stakeholders like local residents and planning regulators are usually concerned on how a particular development can fit in the surrounding environment. Initial visualizations of a proposed development might significantly help to relieve a developments track throughout the planning activity, and could be additionally applied as a highly useful tool to assist and boost communication throughout the design and construction process [47]. Among the major issues concerning a building not reaching its particular evaluation rating is that a design element or other requirements articulated in the initial phase of the project is not executed on-site. There are several potential causes of this: the contractor misinterprets the guidelines; the standards was changed or reduced; requirements were not appropriately written down. BIM can be applied to guarantee that all required elements and contextual information is disseminated throughout the entire construction and design phases of the development [47]. Cole [49] refers to Robinson’s [50] suggestion that for sustainability to turn into a consequential idea it will need novel methods and applications that are integrative and synthetic, not disciplinary and analytic, and that positively build, not merely summation. Azhar [11] argues and suggested that throughout the design and pre-construction phases of a building, the most important decisions concerning sustainable design elements has to be developed. Connecting new methods of simulation and analysis in sustainable design to improved co-ordination of real information using S-BIM during the entire construction process will enable both reduction of rework and waste materials as well as the realization of design for overall performance of innovative buildings and infrastructure through dialogic commitment of stakeholders. Krygiel and Nies [10] advocate that S-BIM can help in the following part of sustainable design; building orientation (choosing an excellent orientation can minimize energy charges), building massing (to examines building shape and enhance the building envelope), day lighting assessment, water harvesting (minimizing water demands in a building), energy modeling (reducing energy demands and
analyzing renewable energy options can lead to low energy costs), sustainable materials (minimizing material demands and using re-cycled products), and site and logistics management (to lessen waste and carbon footprints). As outlined by Hardin in the research on BIM and Construction Management: Proven Tools, Methods and Workflows, it is suggested that design alternatives for sustainability can be monitored and examined in a model together with spatial data to geographically find and import building site data to put it into perspective and play a role in awareness of challenges pertaining to climate, surrounding systems and resources. The building can then be modified and designed with actual coordinates to lessen the impact on and sustainably utilize the surrounding environment to decrease energy demands [51].

Azhar et al. revealed the link between BIM and the LEED rating system, establishing findings that no particular connection occurs between the LEED certification process and BIM-based sustainability analyses as a result of insufficient software, and up to 17 LEED credits and 2 pre-requisites have been recorded, applying results produced by BIM-based sustainability application directly, semi-directly or indirectly, in comparison with conventional approaches. BIM-based sustainability application saves huge resources and time; inconsistences involving the software and manual outcomes were mostly as a result of improperly designed methods [11].

During the life-cycle of a large commercial construction Scheuer and Keoleian [52] discovered that about 95% of energy usage and emissions happen in the operational stage. By using remarkably energy-efficient materials and building operation optimization technologies, the effect to life cycle energy consumption and emissions from the operational stage could be changed to the material production and construction phases [53]. On the research on integration of LCA and BIM software’s. Russell learned that improving the process will not just permit effectiveness in LCA evaluation procedure but in addition allow design modifications to be made before construction and aid building management in the optimization of a building environmental footprint throughout its operation [21]. There are numerous BIM-based applications and devices that have been adopted and created to handle an array of sustainability issues throughout the whole construction process from design development to facilities management, waste reduction and lifecycle analysis [23, 28, 46, 54-56]. While the systems may well support in accomplishing the benefits established by sustainable assessment techniques, the mechanistic and linear strategy needed to obtain credits fail to capture the more humanistic and developmental advantages BIM could provide when it comes to dialogic stakeholder engagement, collective understanding and internalization of sustainability principles that add benefit to the end user by continual analysis and discourse of sustainability through the entire construction and design process with focused stakeholders.

**Recommendation**

Studies have shown that 30% of the waste generated in construction is the result of miscommunication or inadequate information [57, 58]. By integrating S-BIM for construction waste reduction, waste can be prevented and the project personnel can concentrate on building instead of paperwork. Similarly, BIM saves owners time, money and disappointment. Figure 6 indicates the proposed recommendation on how BIM integrates all parties concerned in the project delivery in order to realize optimum cost as well as waste reduction. Prior to the beginning of the project, the designer can demonstrate how the building will perform throughout the project lifecycle, which assists the project team to detect various conflicts at the initial stage that can help them prevent rework as a result of errors found in the design process after work has begun; travel period for construction: teams pick up or drop off plans; shifting materials and content from one staging place to another; materials held too far ahead of time; people awaiting equipment, plans or guidelines on how to proceed; repetitive or unnecessary reporting; expediting material orders. With the recommend model, construction teams know precisely what applications they will require, the amount of a specific material to purchase and when to have the material shipped Almost all issues are captured prior to construction. However, in situations when an issue emerges during construction, it can be solved via the digital model without awaiting a bulletin or new drawings to be issued, shipped and delivered. The recommendation can additionally present a real-time cooperation program for all stakeholders included in a facility life cycle that can minimize inefficiencies and eliminate waste.

**Future Research**

Sustainability is an issue of growing significance in the construction sector. According to the present review, no research has focused on integrating sustainability and CO₂ reduction on construction waste using BIM as CO₂ and waste reduction are complex problems for all sectors. Construction industry assessment sequence considers all aspects of design,
construction and demolition of buildings and infrastructure. Reducing CO₂ emissions ultimately reduces costs of construction and impacts by delivering buildings with low carbon footprint. Future research should focus on making savings on construction sites and making progress on measuring embodied carbon of designs for waste minimization, management and regulation.

Conclusion
The AEC sector continuously needs to execute activities faster at substantially less cost and with greater quality. Structural engineers regularly attempt to employ technological innovation to execute tasks. Among the new strategies that exist at present is BIM. The advantages of employing BIM are clear, particularly how it improves the structural design workflow. Engineers recognize the strength of BIM for more effective and smart design, and the majority of organizations utilizing BIM are confirming its significant benefits.

Acknowledgments
The authors would like to thank members of the Smart Integrated Low Carbon Infrastructure Model (SMART ILOCI MODEL) research program and Ministry of Education Malaysia for funding the research entitled “Systemic Dynamics Modeling of CO₂ Emissions Reduction for Integrated Low Carbon Infrastructure” with cost center number 0153AB-J11, which is part of the Ph.D. research entitled “Integrated Resource Minimization at Construction Sites using Building Information Modeling”.

References
[22] (). Working definition of sustainability for Planning and design source.


