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ARTICLE

Applying BIM to achieve sustainability throughout a building life cycle towards a sustainable BIM model

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ABSTRACT

The research addresses the issue that there is no an integrated approach or model to activate and implement sustainability in a project throughout its life and not benefit from the potentials of Building Information Modelling (BIM) technology in achieving and supporting all sustainability aspects as a human need. Therefore, the research aims to establish and achieve a Sustainable BIM Model for applying within projects throughout their life cycle, managing the relationship between BIM and sustainability, and obtaining best interoperability performance. Consequently, sustainability and the potentials of dealing with it by modern techniques and tools were investigated and identified to simulate its indicators and criteria. Besides, strategies to establish sustainability that can be activated. Then related sustainability indicators to the performance of project aspects were collected and categorized to facilitate linking with BIM platforms. Moreover, the potentials of the overlap between sustainability and many BIM platforms were examined and demonstrated, and their employability in supporting sustainability aspects in a balanced manner. Eventually, a methodology to manage the relationship between BIM and sustainability was deduced and formulated to achieve a Sustainable BIM Model during a building life cycle.

KEYWORDS
Building Information Modelling (BIM); sustainability aspects; stakeholders; life cycle assessment (LCA); sustainable BIM model

Introduction

Many architects have believed that using modern techniques impedes access to building aims that many adopted from the sustainability concept and green buildings (Shoubi et al. 2015; Lu et al. 2017; Maltese et al. 2017; Alwisy et al. 2018; Dave et al. 2018). Also, some architects have employed these techniques for forming, presentation, and economic feasibility without paying attention to the possibility of realizing functions and users' comfort and satisfaction (Aikaterini Mamalougka 2013; East 2013; Motawa and Carter 2013; Kamali et al. 2018). Sustainability by its broad umbrella meets all needs and requirements of a project and users and takes into account the environmental, economic and social aspect (Bragança et al. 2010; McArthur 2015; Chong and Wang 2016). The role of these techniques so as not to stop at the stage of planning and design, but grow to reach all phases of the life cycle of a building (Volk et al. 2014; Enshassi et al. 2016; Okakpu et al. 2018). These technologies are not considered as complicated as others think, but need more effort, experiences and planning to activate them in the field of construction (Alreshidi et al. 2017; Lu et al. 2017; Singh et al. 2017). Building Information Modelling (BIM) technology is considered a multi-use technology and the most interactive and responsive to indicators and changes that occur in a building and a project (Kreider and Messner 2013; Zou et al. 2017; Ahuja et al. 2018). Besides the BIM technology has measured, evaluated and supported some of the performance indicators of a building and a project during its life cycle that can be employed to achieve the concept and aspects of sustainability and green construction throughout a project (Chong and Wang 2016; Nicał and Wodyński 2016; Alwisy et al. 2018; Raouf and Al-Ghamdi 2018). BIM can be linked to all aspects of sustainability during a building life cycle without hurting the aspirations and desires of architects of dazzling presentation, shaping and untraditional formations (McArthur 2015; Bueno et al. 2018). Hence, it can access to all objectives of construction, project and stakeholders without harming the environment and human aspects through a methodology to achieve a

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sustainable BIM model. (Alwan et al. 2015; Khaddaj and Srour 2016; Okakpu et al. 2018). Consequently, a BIM Model that will wholly automate all the principles or indicators of any of the sustainability rating systems has not still arrived.

Research problem

The overall usage and operation potentials of BIM have not been yet benefited from them to achieve sustainability throughout the life of a building. Despite, there is an overlap of features and services that BIM provides with indicators and criteria to accomplish sustainability. On the other hand, many specialists have used BIM to measure, evaluate, and support some indicators of sustainability; if this was deliberately or not, and they have not addressed the rest aspects of sustainability; thus they did not tangibly achieve sustainability. Because there is not an integrated approach or model to activate sustainability and its full indicators in any project during all its life; also, that approach or model does not stop at any stage and does not complete to achieve and undertake sustainability, and it is working on reaching all the objectives of a project. Although, it is relying on BIM will solve the problems of delay for the real implementation of sustainability assessment systems, all their components, and indicators in all aspects and phases of a project life after that.

Research aim and objectives

The research aim is to access a sustainable BIM model for applying in existing and emerging projects throughout life phases to manage the relationship and interoperability between BIM and sustainability towards the best mutual performance. This aim can be achieved through the following objectives:

1. To emphasize and activate the important role of sustainability with its three aspects, and the potentials of dealing with their indicators and strategies by technological means and tools;
2. To investigate and find out the uses and purposes of BIM and its role towards a more positive, especially with sustainability in all the life cycle phases of buildings of their different types;
3. To verify and confirm there have been overlapping relationships, interoperability, and common fields between sustainability and BIM; and
4. To establish and formulate a methodology to manage this overlap and interoperability in fields of work and application between BIM and sustainability to achieve a Sustainable BIM Model throughout the life phases of buildings.

Research methodology

The research depended on the inductive approach to address and demonstrate the concept and importance of sustainability and its relationship to human needs. Sustainability assessment systems were examined and investigated to integrate with LCA. Also, the possibility of dealing with them by technical means such as BIM that was emphasized to simulate the performance indicators of elements of a building during its life phases. Through, sustainability strategies and indicators related to the building performance were identified and classified to manage, evaluate, and develop them; through linking with BIM for achieving the best relationship and interoperability throughout the life cycle of a building. Besides the advanced and developed BIM role was especially demonstrated with sustainability. ~~The analytical approach to~~ study and analyze the overlap between sustainability and BIM towards a sustainable BIM Model. Through the importance of achieving this proposed model that has been examined, clarified and emphasized. The role of cooperation and transparency among stakeholders was confirmed. Requirements and needs to achieve this model, besides obstacles both BIM and potentials of its integration with sustainability, were investigated and categorized. The BIM support benefits of sustainability were analyzed and categorized throughout a building life cycle. The BIM platforms were collected and classified as examples; consequently, they can achieve the performance indicators of sustainability. ~~The deductive approach to~~ emphasize the balance in addressing sustainability during interoperability to achieve its three aspects include the proposed model of a sustainable BIM. Establishing a methodology of managing the relationship between BIM and sustainability due to the overlap between them in areas of application and interoperability that was formulated and deduced to achieve a Sustainable BIM Model and take their advantages.

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Sustainability

Sustainability should fulfil the today needs without hazarding the ability of future generations to meet their needs (Vaughter et al. 2016). The relationship between buildings and the environment can be established based on reducing the negative effects of the external environment on internal spaces. Besides, the negative impacts of construction, operation, and renovation of buildings on the ecosystem balance, and the nature of functions have reconciled (McArthur 2015; Maltese et al. 2017; Alwisy et al. 2018). Benefiting from the natural patterns that may appear in some of the features to help in operating a building by utilizing renewable and clean energy; also, achieving the best life quality in the spaces of a building by accomplishing acoustical, visual and thermal comfort. Another way to benefit from nature is to meet humanitarian psychological needs by achieving the natural variation and its impacts on senses of users and sensations (Bragança et al. 2010). Sustainability presents a set of benchmarks to treat the relationship issues between a building and the environment, increase satisfaction, and achieve integration with the surrounding environment (Maltese et al. 2017; Lützkendorf 2018). Hence, producing a healthy community; also, buildings should represent as a skin of their occupants according to their needs without harming the cycles of the balanced nature through being buildings a part of one or more of these cycles (Shamseldin 2018). The various sustainability issues interpenetrate, and their interaction with buildings in surrounding become essential. A project is sustainable only when all sustainability dimensions are treated (cultural, social, economic and environmental). Generally, the environmental issues participate in interesting in reducing emissions, wastes and pollutants, and reducing the use of non-renewable materials and water (Bonenberg and Wei 2015). Many sustainability assessment methods of buildings have the most important objectives (Enshassi et al. 2016; Vaughter et al. 2016; Alwisy et al. 2018):

1. To optimize of site potentials;
2. To preserve regional and cultural identity;
3. To minimize energy consumption;
4. To protect and conserve water resources;
5. To use environmentally friendly materials and products;
6. To achieve a healthy and convenient indoor climate; and
7. To improve operation and maintenance applications.

Two extreme trends can be recognized current time: the evolution towards the best usability through a mutual understanding and simplicity; and the complexity and diversity of indicators from different operators (Bragança et al. 2010; McArthur 2015). Although, sustainability seeks to meet human needs and preserve environment sources during the last two decades. However, the environmental influence of products and processes in human was received increasing attention. Many researchers addressed the results of human's satisfaction about modifications of a product conceived for decreasing the consumption of resources (Aziz et al. 2016). Despite a sustainable building can be described as a subset of sustainable development requires the continuous process of balance among the three aspects of sustainability: environmental, social and economic. Therefore, ensuring sustainability for future generations (ALwaer and Clements-Croome 2010).

Sustainability assessment systems

According to the sustainability principles, evaluation methods have been developed to guarantee that buildings meet environmental standards. BREEAM, LEED, CASBEE, Green Globes, LBC, CESBA, and other rating systems are not more just evaluation or a certification. They have to be achieved early throughout a building life cycle from starting the design stage to the operation stage. Their strong relationship among design tools enhances a strong integration with BIM to associate with defined tools will provide more reliable conclusions with minimal effort (Shamseldin 2018; Vaughter et al. 2016; Maltese et al. 2017). Sustainability assessment based on LEED and BREEAM is an evaluation system, was widely adopted and was internationally considered as a powerful rating system. In addition to CESBA tries to execute the harmonization of indicators involved in different rating systems to support a uniform rate and the quality of sustainability standards, which are now adopting different criteria or indicators in each country. This complexity and the need for certified results from early steps claim for integrating with existing tools and methods, such as BIM (Bank et al. 2010; Nicał and Wodyński 2016; Kamali et al. 2018). Despite, an assessment field regulates a single indicator and certainly relates to other requirements. Thus, the most advanced visualization techniques are the most benefit to understand and appreciate these types of unrevealed relationships and interconnected outcomes. LEED and BREEAM are the first international generation tools, and their applicability enhances the performance from the various viewpoints of energy, comfort, environment, pollution, transport, management and material (Bank et al. 2010; Maltese et al. 2017). Then the sustainable design practices and the design data are entered into an energy simulation tool

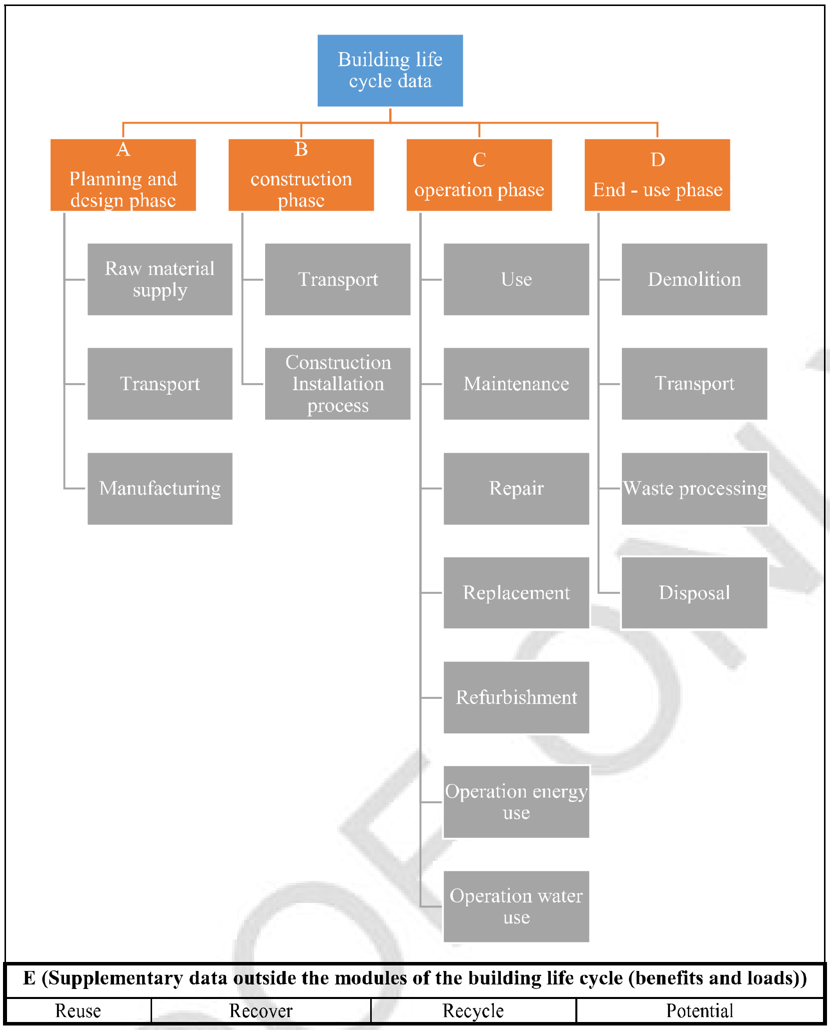

Figure 1. The life cycle of a building is divided into phases or modules (Cabeza et al. 2014; Alwisy et al. 2018; Lützkendorf 2018).

to analyze the building performance. Energy simulation packages such as Energy Plus, Ecotect, DesignBuilder, and IES Virtual Environment to study the building design characteristics: thermal insulation, glazing, shading, solar gain, radiation, climatic response, ventilation, HVAC systems, dynamics and thermals (Shoubi et al. 2015). The required information to analyze energy consumption in buildings is very complicated and involves information regarding its external environment, shape, mass, facility loads, lighting systems and airflow. Consequently, for the accurate prediction about energy consumption, it should use integrated simulation tools and models (Habibi 2017). Determining models consider fundamentally for assessment systems that intend to generate comparable assessment outcomes. Life cycle assessment (LCA) is commonly used and generally integrated with rating systems (Scheuer and Keoleian 2002; Kylili et al. 2016). If it is performed early enough in the design phase, it will help to evaluate the ease of deconstruction and recycle the design alternatives. The design aim is to minimize using resources and environmental pollution at the same time, guaranteeing a high reusing and possible recycling at the end of a life cycle (Alwisy et al. 2018). These values have been identified and are involved in the results of LCA in the form of the group of parameters represents a total result, were divided during the life cycle phases or modules in Figure 1. LCA has been used in the related international and European standards to model a building life cycle (Lützkendorf 2018). The purpose for this is to make a clear differentiation between energy and material flows in a building life cycle as shown in the modules (A to D) in Figure 1. In addition to the possible effects of recycling can occur outside a building life cycle as a potential not close under the precondition of a regular deconstruction of a building. Module (E) represents the benefits and loads that exceed the system outside in a building life cycle.

BIM platforms have generated intelligent data to conduct the holistic analysis of a building in terms of simulation and visualization to performance, energy and form. These provide for designers the potentials for testing the design to improve performance during a building life cycle (Motawa and Carter 2013; Alwisy et al. 2018).

Strategies for establishing sustainability during a building life cycle

The project sustainability indicators

They give data about the industry influences and the impacts of constructing and operating buildings. Different methods of indicators exist due to differences among communities, local industries, environment and geography. Although, some differences among the lists of indicators most of them deal directly or indirectly with the following main issues: environmental pressure; resource consumption; energy and water efficiency; comfort; indoor air quality; and, life-cycle costs. The value that expresses a studied indicator is reached by combining different metrics (Bragança et al. 2010; Kamali et al. 2018).

Managing and evaluating sustainability during the life of a building

The sustainability evaluation methods of a building can be oriented to different analysis scales: materials and products of construction, components of a building, a free place, and a neighbourhood (Kreiner et al. 2015). By analyzing the most important fields of the sustainability enhancement and evaluation systems and tools, it is possible to distinguish three models of evaluation methods (Vaughter et al. 2016; Lützkendorf 2018):

1. Systems to manage the building performance (Performance-Based Design);
2. Sustainable building evaluation and certification systems; and
3. LCA systems.

These models of evaluation methods have based on managing a building performance and the integrated analysis of the life cycle of buildings.

Sustainable building evaluation and certification

The evaluation and certification systems and tools aim to enhance a building life cycle by the best integration of sustainability aspects that interest in achieving other common decision standards (Bragança et al. 2010). The most important issue to limit the real implementation of sustainability is a large number of indicators and factors. These require project teams have to deal with by many methodologies have previously been presented that include hundreds of metrics or parameters. Most of them are not standard in the field of a building; also, they are difficult to deal with them from many project teams. Therefore, the selected performance indicators must meet the following criteria (ALwaer and Clements-Croome 2010; Hooper et al. 2015; Singh et al. 2017):

1. Helping in determining the choice in decisions;
2. Being usable by anyone, including designers, and occupants and clear interface;
3. Being quantifiable and scientifically valid;
4. Allowing partners to compare and contrast different choices;
5. Being a flexible and multipurpose of a general nature;
6. Being used in different types of buildings and sensitive to change;
7. Accessing data should be easy and no obstacles during processes;
8. Comprehensive usage at different stages in a building life cycle;
9. Redefining specific problems can affect sustainable buildings for current and future developments; and
10. Being effect on cost.

From the previous strategies can gather all aspects of acoustics, thermal, lighting, energy efficiency, sustainability of materials, the performance of the rest of the building elements in Figure 2. Consequently, making a design more reasonable and optimized, and eventually achieving the accordance with sustainability benchmarks. At the same time, the measures of sustainability will also complete the immediate expression in the building design; thereby, ensuring project results will meet the criteria of green buildings (Bonenberg and Wei 2015).

These indicators have resulted from the process of identifying the sustainability appearances that can be analyzed and evaluated during a life cycle to achieve a Sustainable BIM Model (Bragança et al. 2010; Lützkendorf 2018). The proposed methodology to be

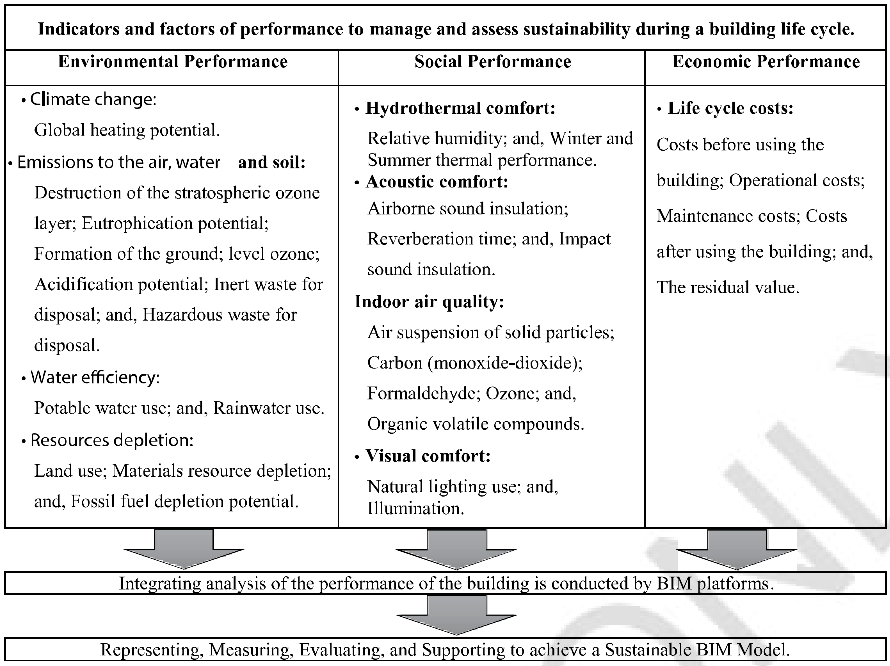

Figure 2. Shows the most important aims of many strategies for assessing a sustainable building based on indicators and parameters by BIM.

established by integrating sustainability with BIM will be one of the future ways to enhance the sustainability performance of buildings, which is the overall concept of a Sustainable BIM Model (Kreiner et al. 2015).

However, when the life quality and BIM in a building life cycle is addressed related to sustainability and created a sustainable built environment that has the following benefits (McArthur 2015; Aziz et al. 2016; Enshassi et al. 2016):

1. Shortest time for making decisions;
2. The cost of effective operating;
3. Resource for making decisions;
4. Best documentation system;
5. Collaboration and work flexibility; and
6. Updated data and conflict disclosure.

BIM during a project life cycle

BIM includes information and communication technology frameworks and technologies that can enhance stakeholders' collaboration over a building life cycle by systems to insert, extract, update, or modify data in a BIM model (Golabchi et al. 2013; Bonenberg and Wei 2015; Aziz et al. 2016; Ghaffarianhoseini et al. 2017; Okakpu et al. 2018). BIM applications offer information is more usable for visualizations and simulations than the general and separate project tools such as technical 2D/3D drawings and documents (Alwisy et al. 2018). BIM is supposed to change the way that the built environment operates (Ahmad et al. 2013; Singh and Singh 2014). Studies related to BIM have moved from the fundamental functions to save, connect and exchange a project to which based technical information to include all information and knowledge analysis of the project life cycle that benefits all (East 2013; Motawa and Carter 2013; Pärn et al. 2017). BIM was defined as the action to establish a digital model of a building or a project for the goal of visualizing, analyzing, treating conflicts, checking code criteria, cost, as built, budgeting and other many objectives during a project life cycle (Singh et al. 2017). BIM Uses can fundamentally be classified based on the objectives for executing BIM during the life of a building (Barlish and Sullivan 2012; Kreider and Messner 2013; Zou et al. 2017). These objectives and features of BIM use are shown in Figure 3. The purposes are shown in Figure 4. The key objectives of using BIM are achieved by implementing these purposes.

BIM was taken into account as the most oriented process methodology and innovation in the construction field. Even if BIM already was being practised for several years in the building sector. BIM only was widely approved a few years ago from governments, local authorities, and private firms of a new building and other existing (Ghaffarianhoseini et al. 2017; Maltese et al. 2017). Due to needing to apply evaluation systems; building process actors; technological solutions for building and services; users' needs; and, client requirements are varied. Thus, the need to exchange an enormous amount of information about a common exchange protocol has grown (Bradley et al. 2016; Nicał and Wodyński 2016). The answer to this need can be given by the Industry Foundation Classes (IFC) that is currently the most advanced non-proprietary information exchange format for the building sector (Porwal and Hewage 2013). FC not only provides an instrument to exchange information; but also, IFC offers a holistic framework and a classification for addressing complex buildings (Chen et al. 2018). IFC concept feasibility was demonstrated by saving a set of standards came from evaluation systems into a BIM model using IFC attributes. Those attributes being available and they produce dedicated characteristic sets when they require. Those all attributes are going to do in three different assessment systems (LEED, BREEAM and CESBA). Also, for various building stages or elements (core and shell) (Maltese et al. 2017).

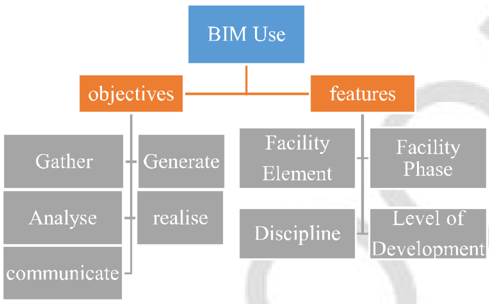

Figure 3. The objectives and features of a BIM Use (Kreider and Messner 2013).

The BIM project execution-planning guide presents a structured approach to outline the implementation of BIM on a project. The procedure includes the following four-stage (Bryde et al. 2013; Kreider and Messner 2013; Cavka et al. 2017):

1. High-value BIM uses, has to be identified within the project planning, design, construction, and operation stages;
2. The production process of maps is designed to perform the BIM processes;
3. The BIM deliverables in the form of information exchange are defined; and
4. The infrastructure in the form of agreements, communication methods, technology, and quality control, is going to develop to promote the execution.

Gerrard et al. (2010), Cavka et al. (2017) and Singh et al. (2017) stated that BIM is a methodology of information technology that includes designing, energy efficiency analysis during a project life cycle linked to object depended on parametric modelling, which includes geometric and non-geometric information. BIM works to develop building information and detailed analysis during the life cycle as shown in Table 1, which helps in making decisions to final sudden changes.

Interactive relationship and common areas between BIM and sustainability to achieve a sustainable BIM model

The sustainability framework measures the performance of a built environment that allows capturing the status of the characteristics of this built environment.

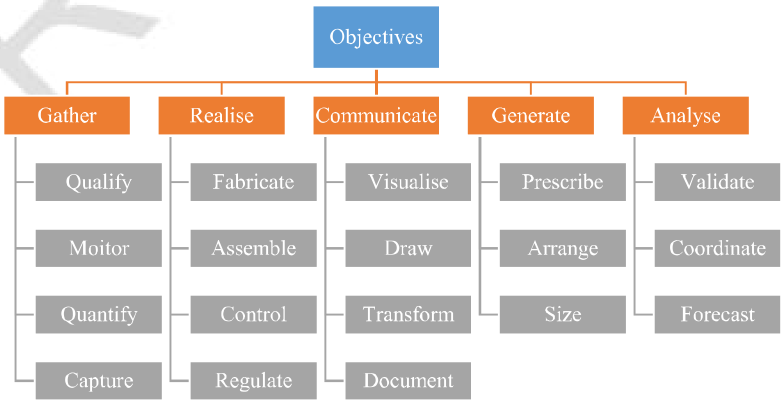

Figure 4. Shows the purposes of using BIM according to its five core objectives (Bryde et al. 2013; Kreider and Messner 2013; Bradley et al. 2016).

Table 1. Shows the primary and secondary benefits of BIM uses from the planning phase to the demolish phase (Hannele et al. 2012; Golabchi et al. 2013; Kreider and Messner 2013; Aziz et al. 2016; Singh et al. 2017; Alwisy et al. 2018; Okakpu et al. 2018).

Planning		Design		Construction		Operation		Renovation and Demolish	
Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
Existing condition modelling		Design reviews	Code validation	3D control and planning	Digital fabrication	Building analysis system	Disaster planning	Renovate	
Cost estimation		Energy analysis	Structure analysis	Site use planning	Construction system design	Maintenance scheduling	Space management planning	Visualize	
Phase planning		Design authoring	Other Engineering analysis	Recording models			Asset management	Schedule	
Site analysis		3D coordination	Mechanical analysis					Navigate	
Programming		LEED evaluation	Lighting analysis						
Design (BIM)						**As built (BIM)**			

Therefore, what requires to be done and will be decided; also, how design, operation and construction aspects, can be enhanced to achieve policies of sustainable evolution (Raouf and Al-Ghamdi 2018). BIM has been guided towards the emerging and existing buildings and related to processes and modules as shown Figure 1. The study investigated many accelerated changes and up-to-date improvements to not only orient implementation and research in many fields are linked BIM to but also extend researching because of recent developments of BIM. The implementation of BIM led to profound changes in processes and information flow throughout a building life cycle. On the other hand, it has gathered considerable advantages like mitigating risks and improving data management for achieving sustainability (Volk et al. 2014; Enshassi et al. 2016; Ghaffarianhoseini et al. 2017; Zou et al. 2017).

The importance and benefits to achieve a sustainable BIM model

The specialized refurbishment or deconstruction processes can also benefit from using BIM through decision-making that is improved and supported in projects for refurbishing, deconstructing, reducing costs, enhancing collaboration and documentation, and managing data and visualizations (Porwal and Hewage 2013; McArthur 2015; Ahuja et al. 2018). Therefore, BIM will support ecological problems are not taken into consideration like resource efficiency, the achievement possibility of recycling qualities and their rates for recyclability, the ability to gather component links, separation of material layers and composites, treating emissions like (noise, dust, vibrations) (Lützkendorf 2018; Okakpu et al. 2018). Thus, particular protective actions are going to be taken that can be simulated or enhanced by BIM. As the development of design and maintenance functions demands standardized levels of details of BIM components such as Construction Operations Building information exchange (COBie) is an essential guide of using BIM through project management. Although COBie involves material and sustainability data, it excludes data on architectural elements such as slabs, walls, footing, roof, ramps and stairs, which are essential for planning, design, construction and refurbishment (East 2013; Pärn et al. 2017). Additionally, the many coexistent concepts to evaluate the quality of a BIM model can benefit from harmonization so as not to impeding interoperability and data exchange during as-built BIM (Nicał and Wodyński 2016).

The majority of existing buildings are not maintained or deconstructed by BIM until now; also, stakeholders' collaboration can remain ineffective (Porwal and Hewage 2013; Ghaffarianhoseini et al. 2017). Many potentials and particularly BIM linked to the management of a building (Hannele et al. 2012). However, regarding deconstruction; activities, functions, specific process or interaction maps of BIM have not been developed or implemented yet. Due to dominant restrictions of time and cost in construction, the research focuses on the stages of cost optimizations and digitally supported collaboration by BIM to achieve "Sustainable BIM." During the link between BIM and sustainability, BIM introduces programs for decreasing energy consumption in a building life cycle. Eventually, the enhancement of BIM role has been investigating that proposes renewals based on energy that was involved in the following predominant themes like water, emissions; waste reduction and materials; and indoor environmental quality (McArthur 2015; Khaddaj and Srour 2016). Chong and Wang (2016) addressed enhancements and promotions of performance where BIM has the capability of simulating energy and using water of a building; therefore, it allows a user to improve the consumption of energy and water from various system sources. In addition to the integration of BIM and LCA to measure the environmental influences of a building is obtained through BIM directly includes LCA processes such as quantified materials and organized environmental information in integrated databases (Kreiner et al. 2015; Bueno et al. 2018). This method is more computational when takes environmental influences into consideration like materials are elected during the preparatory design phase. Studies have evaluated the BIM potentials within a design confirmation process to diagnose design mistakes that can appear in construction waste during the rework phase (Won et al. 2016; Won and Cheng 2017). The studies revealed that BIM has an accurate method that will select proper dimensions of materials, which will maximize from reusing construction residues, thus construction wastes will minimize (Raouf and Al-Ghamdi 2018). Consequently, BIM allows evaluating the effectiveness of green applications for a building is supporting what BREEAM or LEED proposes to accomplish and promote in a Sustainable BIM model.

Overlap potentials between the two concepts remain the BIM use for modelling energy and subsequently defining the retrofit scope of existing and new buildings (Habibi 2017). Promoting driven energy refurbishment of existing buildings by BIM will help accomplish sustainability ratings and certifications in a shorter period (Hannele et al. 2012). For example, Building Automation Systems (BAS) and Building Energy Management and Control System (EMCS) provide information that can be spread to calibrate parameters in an energy simulation model based on the virtual reality tools (Underwood and Isikdag 2010; Ahmad et al. 2013; Khaddaj and Srour 2016; Paes et al. 2017).

The role of cooperation and transparency to achieve a sustainable BIM model

Throughout the construction industry, collaboration and data exchange are still mainly based on documentation (Porwal and Hewage 2013; Ahuja et al. 2018). The collaboration is depended on by BIM during the complete life cycle of a building. It can enhance information and process management with a central method and facilitate role and responsibility management (Bonenberg and Wei 2015; Alreshidi et al. 2017; Singh et al. 2017; Zou et al. 2017). Especially in new buildings, the collaboration by BIM is growing due to enhancing capacities of communication media, servers, cloud computing, mobile devices, and augmented reality methods (Enshassi et al. 2016). BIM collaboration systems are available, concentrate on the functionalities of managing content, viewing, and reporting rather than a model formulation or system administration yet, but also they are more developed (Ghaffarianhoseini et al. 2017; Zanni et al. 2017).

The requirements to achieve a sustainable BIM model

It is necessary to increase stakeholders' awareness of benefits of BIM technologies and how to execute those technologies to refurbish in existing buildings; also, taking into account in new buildings is needed to be collaboratively organized the project. Besides, ideal outcomes are being achieved to enhance the applicability of BIM tools in the energy of a building to retrofit and improve projects. Therefore, to achieve Sustainable BIM, there are three types of requirements (Khaddaj and Srour 2016; Ghaffarianhoseini et al. 2017; Ahuja et al. 2018; Bueno et al. 2018):

1. Technical requirements: BIM during energy retrofitting projects are numerous and are divided based on the stages of the project: Pre-Energy

Modelling, Energy Modelling and Refurbishment Options;

2. Informational requirements: there are challenges in interoperability that hinder the exchange of building data across BIM platforms. As BIM technical functionalities grow, the information exchange protocols mature in parallel to help the implementation of BIM at any energy simulation software; and
3. Organizational requirements: stakeholders' awareness about the benefits of BIM technologies is encouraged. Training and education on how to implement these technologies for the energy of operating buildings are needed to achieve optimal results.

Obstacles in the way of achieving a sustainable BIM model

The sustainable design ensures decreasing life-cycle costs of a building by BIM that can transfer in other software for further analysis of occupant's comfort, environment and energy performance. Therefore, it must stand on the obstacles of applying BIM (Demian and Walters 2014; Enshassi et al. 2016; Pärn et al. 2017; Singh et al. 2017; Sun et al. 2015; Alwisy et al. 2018):

1. Need to educate professionals about BIM and lack of managers' and owners' awareness and support;
2. Lack of data interoperability and protocols;
3. Change in workflows and inappropriate business models;
4. No well-developed practical strategies and standards;
5. Habitual resistance to change;
6. Cost of specialized software or platforms;
7. Cost of time, training and required hardware upgrades;
8. Contractual environment and responsibility between stakeholders;
9. Ownership of the BIM information and its copyright;
10. Fragmented nature of the construction industry and lack of cooperation from other industry partners;
11. Accessibility of BIM tools;
12. Safety and reliability of building information;
13. Missing the insurance framework for BIM application;
14. Need for sophisticated information management;
15. Not familiar enough with BIM capabilities; and
16. The requirement of computable digital design data.

The key six obstacles of integrating between BIM and sustainability that require to be investigated and taken into consideration during achieve sustainability by BIM (Azhar et al. 2015; Enshassi et al. 2016; Oduyemi and Okoroh 2016; Chong et al. 2017; Ahuja et al. 2018; Alwisy et al. 2018):

1. The weak interoperability among different sustainable through BIM platforms;
2. Lack of support for the construction and operation stages to achieve sustainability;
3. Lack of industry criteria holistically covering the different application fields of sustainability through BIM and studies on the best practices of sustainable through BIM projects;
4. Low industrial acceptance of sustainable through BIM platforms;
5. Low accuracy of BIM-based prediction models; and
6. The lack of appropriate project delivery approaches.

Therefore, future research opportunities exist in these fields to further support sustainability through BIM.

Supporting BIM of sustainability during a building life cycle

Sustainability of buildings has become from vital considerations in the design of buildings because of making decisions in the early design phase has significant impacts on the actual environment of buildings. Conventional design methods are restricted in term of continuous analyze of sustainability during the design process due to fragmented data (Yu et al. 2016; Gerrish et al. 2017; Ahuja et al. 2018; Alwisy et al. 2018). A BIM model can be used as a database to exchange and integrate information based on IFC (Porwal and Hewage 2013; Bueno et al. 2018). The current research confirms that the benefits of using BIM in the life cycle of projects to achieve sustainability can be classified into the three aspects as shown in Table 2.

In the design phase, BIM allows multidisciplinary data to be superimposed on the same model to produce an opportunity of sustainability criteria for being incorporated in the design process (Enshassi et al. 2016; Singh et al. 2017; Bueno et al. 2018). With the aid of these BIM platforms, architects and engineers

Table 2. Shows benefits of using BIM to achieve sustainability during the life cycle of projects, are classified into three aspects (Schlueter and Thesseling 2009; Grilo and Jardim-Goncalves 2010; Azhar et al. 2015; Porwal and Hewage 2013; Bueno et al. 2018).

First	Second	Third
BIM information can exchange among users are multidisciplinary with various analysis tools of sustainability. For example, a BIM-based modular web service framework can integrate the data necessary for sustainable design, automation design assessment processes, and facilitate simple updates on a building model a common and shared application.	BIM software can present visual data related to the building performance and process, consequently permit project partners like designers, contractors, and occupants to make decisions are the most appropriate to the environment. For example, a BIM-based energy consumption evaluation of a building was produced to provide a graphical visualization of the performance of energy indicators.	BIM can improve communication and collaboration of various stakeholders correlated with sustainable design, construction, and operation. This integrated software offers a new framework for all stakeholders who are working on the same project for a shared vision was controlled by these platforms. Therefore, this promotes relationships among all participants in the building industry that previously suffered from partial relationships.

can more effectively share knowledge linked to sustainability like a type of lighting or energy consumption. Hence, sustainability analysis can easily integrate into the design stage and help designers benefiting the existing building information sets to improve the default configuration for building performance simulations during the early stages of the new building design (Russell-Smith et al. 2015; Lu et al. 2017).

In the construction phase, BIM has a vital role in decreasing the impact on the environment through several aspects like noise pollution, carbon emissions, resource consumption, and waste generation (Singh et al. 2017). BIM presents many efficient proposals for decreasing these influences as a 3D BIM model was introduced to estimate the CO_2 footprint in a house building phase and provide guidelines for developing construction activity schedule and minimizing correlated emissions (Suermann and Issa 2010; Di Giuda et al. 2015). In the operation phase, BIM is considered an invaluable tool in observing the sustainability performance of buildings in monitoring the sustainability performance of buildings is very critical. In addition to it can check the real performance compared with the objectives sets in the design stage. That is a complex responsibility such as data of buildings during this stage must be gathered from stakeholders in various stages (Azhar et al. 2015; Aziz et al. 2016; Cavka et al. 2017). BIM was used in this stage by concentrating on energy management. Similarly, a BIM-based automatic method to help project managers to streamline the process of troubleshooting HVAC-related obstacles (Schlueter and Thesseling 2009; Dave et al. 2018).

In the renovation phase, BIM supports maintenance and repair for recovering energy and capital investments and benefiting from managing waste (Bueno et al. 2018). In the demolition phase, BIM supports to make a clear differentiation between energy and material flows; and, benefiting from managing waste to recycle, reuse, recover and potentials (Cabeza et al. 2014; Lützkendorf 2018). Therefore, it can summarize BIM potentials to support various aspects of sustainability during a building life cycle, as shown in Table 3.

However, the use of BIM for the building management during the operation phase until the demolition phase is still limited, because of the four main reasons (Chong et al. 2017; Hong et al. 2017; Maltese et al. 2017; Sun et al. 2015):

1. Lack of awareness about the produced benefits from using a Sustainable BIM for operating the management;
2. Lack of clear definition of the information exchange for operating the management;
3. An innovative insurance system is needed to adopt the social sustainability of the building; and
4. Lack of clearly defined use cases in compliance with industry criteria and guidelines for partners to follow.

Specialists believe BIM platforms or software; provide feasible solutions to address sustainability problems on project renewals (Alwisy et al. 2018). Despite the appraisal of building wastes in new buildings cannot be performed; therefore, more efforts are needed to increase applications and platforms of existing systems based on BIM (Nicał and Wodyński 2016; Won and Cheng 2017).

BIM platforms to achieve a sustainable BIM model

The current BIM platforms and applications that have been developed to enhance the sustainability performance of buildings during life cycle stages, which a Sustainable BIM Model will base on. Twelve platforms of BIM were designed and developed to address sustainable building issues, were chosen from the BIM tools matrix. The BIM forum collected the shared knowledge of BIM industry as in Table 4.

Table 3. BIM supports various aspects of sustainability during the building life cycle (London et al. 2010; Suermann and Issa 2010; Wang and Hamilton 2010; Fernández-Solís and Mutis 2011; Chong et al. 2017; Bueno et al. 2018).

Design	Construction	Operation	Renovation	Demolition
Facilitating information exchange and integrating it; providing visualized building performance analysis and simulation; and evaluating design alternatives.	Analyzing different environmental influences of the construction process; waste reduction; and improving productivity and performance of construction.	Helping to observer the sustainability performance of a building.	Supporting the recovering of energy and capital investments; and benefiting from managing waste.	Difference between energy and material flows; and waste recycle, reuse and recover.

The importance of balance while dealing with sustainability for meeting its aspects in a sustainable BIM model

From investigating and analyzing during this study that has demonstrated and emphasized on the interoperability among these aspects and they cannot perform without the others as it has appeared in the previous sections. Besides, it has been demonstrated many credits and indicators in sustainability assessment systems can be integrated into BIM platforms. Therefore, allowing of the sustainability assessment process to be conducted during the project life cycle, needs to be balanced among sustainability aspects towards a sustainable BIM model.

Economic sustainability as the first aspect

BIM manages the costs and scheduling period of all stages and procedures to serve the project economics. BIM reduces modification costs, decreases the amount of wasted costly materials, helps with the verification of suppliers' performance with BIM information, and presents integrated unit price information along with estimating cost systems to extract bills of quantities (Kylili et al. 2016; Won et al. 2016; Won and Cheng 2017; Kamali et al. 2018).

Social sustainability as the second aspect

Social sustainability highlighted two areas (Porwal and Hewage 2013; Chong et al. 2017; Maltese et al. 2017; Ahuja et al. 2018; Bueno et al. 2018):

1. Design of human comfort that addresses how owners can examine and give feedback on the BIM design on a 3D visualization before construction begins; and
2. Comprehensive collaboration in design practice that examines an improved working relationship among stakeholders in what is traditionally a fragmented design process.

BIM implementation for identifying the causes of hazards; managing safety; visualizing interactions between aspects of construction; and detecting dangerous work with a site, time, and environment (Kreiner et al. 2015; Enshassi et al. 2016). It can be accomplished sustainability evaluations by using BIM platforms to evaluate the ecological and carbon footprint, and collectively a life cycle cost analysis (Hannele et al. 2012; Khaddaj and Srour 2016; Kylili et al. 2016; Kamali et al. 2018). Various design options can be instantly appraised by BIM to decide which solution is the most sustainable (Singh et al. 2017). However, social aspects as their related decisions involved what they made at starting before agreeing on a building itself. Also, a social sustainability evaluation technique included factors related to functional, aesthetic, and innovative design strategies (usability, functionality, architectural ideas, and occupants' safety and comfort (accessibility, health etc.)) (Aikaterini Mamalougka 2013; Won and Cheng 2017).

Environmental sustainability as the third aspect

The sustainable building design is associated with analysis, predicting and design optimization to reduce environmental impacts by reducing energy consumption, carbon footprint and using clean water (Kylili et al. 2016). BIM allows for data from different sources to be used and re-used for various purposes. Therefore, sustainability standards include nine topics that represent categories of primary concern for sustainable development such as sustainable sites; water efficiency; energy, climate and atmosphere; materials and resources; indoor environmental quality; emissions; solar and daylighting; acoustic; and natural ventilation (Alwan et al. 2015; Kreiner et al. 2015; Kamali et al. 2018).

A proposed methodology for managing the overlap and interoperability of BIM with sustainability to achieve a sustainable BIM model

The research seeks to deduce and develop a practical model for a sustainable BIM that can assist current

TABLE 4. Collects twelve common types of BIM platforms and their functions used for indicators and factors of performance to manage, assess, and achieve sustainability during the life cycle (Name et al. 2011; Lu et al. 2017).

	Indicators of performance							
BIM (Platforms or Software)	Energy	Carbon emissions	Natural ventilation	Solar & daylighting	Acoustic	Water	Users	Use
Autodesk® Green Building Studio	√	√	√	√		√	A/D	De/OM
Integrated Environmental Solutions® Virtual Environment	√	√	√	√		√	A/O/E/D	De
Bentley Hevacomp	√	√	√				C/E/D	De
AECOsim	√	√		√			C/E/D	De
EnergyPlus	√	√		√		√	E/A	De
HEED	√	√					A/O/D/C	De
Design Builder Simulation	√	√	√	√			A/E/C	De
eQUEST	√		√	√			A/E/C	OM/C/ De
DOE2	√		√	√			A/E/C/G /U	De
FloVENT			√				E	De
ODEON Room Acoustics Software					√		A/E	De
TRNSYS	√		√	√			A/E	De

(A) Architects; (D) Designers; (C) Construction; (E) Engineers; (De) Design; (U) Utility companies; (O) Owner; (G) Government; (C) Consultants; and, (OM) Operation and Maintenance.

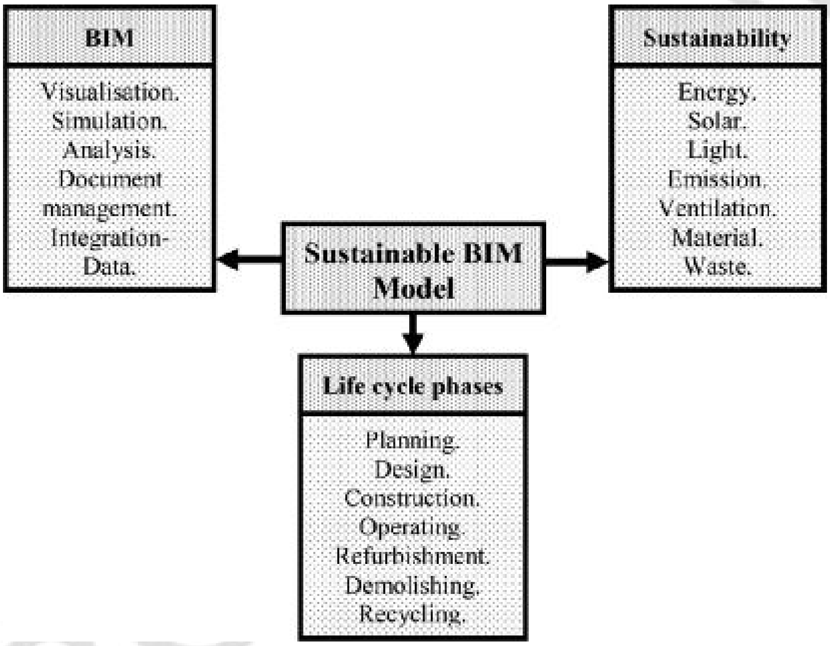

Figure 5. Shows the establishment elements of the sustainable BIM model.

industry practices to decrease the negatives of collaborative work and promote the positives towards sustainability. A sustainable BIM model that is going to thoroughly automate all the points or credits of any of a rating system has not still achieved (Raouf and Al-Ghamdi 2018). Therefore, this study proposes a methodology has been deduced to manage the relationship between BIM and sustainability during the life cycle of a building; the study addressed its elements and components. These components aim to make a critical decision. The methodology components will be displayed in the following section, provide the descriptions of the elements that shape the accomplishment processes of a Sustainable BIM Model.

The elements and components of the methodology to achieve the sustainable BIM model

The first step, the elements were identified and defined (BIM-sustainability-life cycle phases) during the current study Figure 5.

The second step, how to manage the relationship between these elements? Sustainable BIM Model elements need to be understood and identified; also, their components and the role each of them. In addition to the support points, guidance, and services that can be used to manage the relationship among these elements successfully during the life cycle of a building as shown in Figure 6. First, the relationship

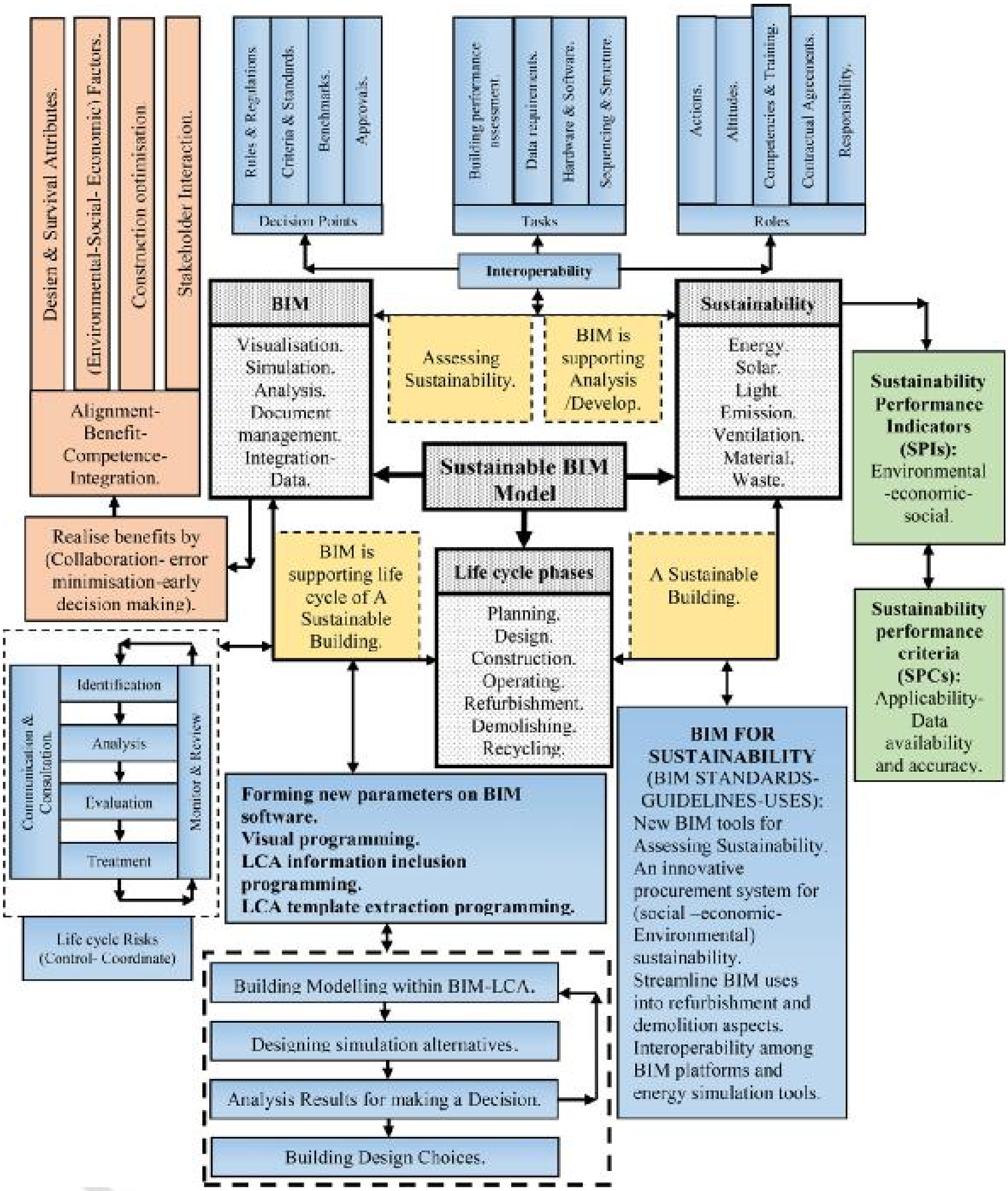

Figure 6. Shows the proposed methodology to achieve the sustainable BIM model.

between sustainability and the life cycle phases is demonstrated and emphasized through Sustainability Performance Indicators (SPIs) can be identified in terms of three aspects (environmental-economic-social). Moreover, sustainability performance criteria (SPCs) during life cycle phases should characterize with applicability, data availability, and accuracy. To can select BIM to achieve sustainability or new BIM tools for assessing it that based on an innovative procurement system for social, economic and environmental sustainability or streamlining BIM uses into the refurbishment and demolition aspects. As well as interoperability among BIM platforms and simulation tools for energy, solar, light, emissions, ventilation, material and waste during life cycle phases to achieve (a Sustainable Building).

Second, the relationship between BIM and life cycle phases that is demonstrated and emphasized by forming new parameters on BIM platforms, visual programming, LCA information inclusion programming, and LCA template extraction programming. These all need Building modelling within BIM-LCA, designing simulation alternatives, the results of the analysis for making a decision (or return to BIM-LCA), and building design choices. Consequently, BIM is supporting life cycle phases of A Sustainable Building by the framework of life cycle risks through control and coordinate.

Third, the relationship between BIM and sustainability during life cycle phases. Interoperability between them that based on decision points, tasks, and roles demonstrates and emphasizes this relationship. BIM is supporting analysis and development of assessing sustainability by visualization, simulation, analysis, document management, and integration-data. Benefits are realized in collaboration- error minimization-early decision making to achieve design and survival attributes, environmental-social-economic factors, construction optimization, and stakeholder Interaction. These all at a frame of alignment, benefit, competence and integration. Hence, Figure 6 demonstrates the proposed methodology for managing the relationship between sustainability and BIM during the phases of the life cycle of a building to achieve the Sustainable BIM Model, which clarify the relationships among the core elements of this model and how to each of them supports the others.

Discussion

Through strategies for establishing sustainability during a building life cycle, investigated and analyzed sustainability enhancement fields and their evaluation systems and tools. It is possible to distinguish the different models of evaluation methods of rating systems, but all of them agree on the performance of the building elements and their impact on the users' performance in facing the external environment. Incorporating and including green assessment criteria into BIM tools and guidelines can force all stakeholders and BIM model developers to create a BIM model meets sustainability requirements. Executing a virtual model is considered a key base in the proposed methodology. In addition to this model has to achieve minimum specifications to fulfil the Sustainable BIM Model and execute the required limits to stakeholders' requirements.

The change towards sustainability is occurring with help existing technological enhancements and components; also, processes of building performance of benchmark platforms, and processes of BIM are realized and outlined in a more detailed framework. Therefore, BIM standards and guidelines should include a set of requirements within the BIM tools to respond with sustainability rating systems. The evaluation has to make the characteristics of a building and the performance simulation by using a tool of virtual reality in a project to deal with the social aspect of sustainability. The study has classified BIM platforms as shown in Table 4 to enhance and integrate with the assessment indicators of the sustainability aspects during life cycle phases were listed in Figure 2 will work by the sustainable BIM model Figure 6 and there is more. However, the use of BIM for managing a building during the operation phase until the demolition phase is still limited, because of the four main reasons that the study investigated and stated.

Mainly, BIM has depended on using cycles of designing, constructing, analyzing, and making decisions during the building performance evaluation is implemented in response to sustainability; also, during the post-occupancy phase. The method of the LCA after linking to the proposed model can treat the fragmented real nature of the life of a building has led to the complex integration of various information during the building life cycle. Life cycle assessment methods and building assessment tools have positive contributions to achieving sustainability goals that have their aspects. For instance, the weight of each parameter and standard may change in the assessment between methods, which can be solved by developing BIM tools are based on the methodology to achieve the Sustainable BIM Model.

Conclusions

The research presents a methodology that will achieve and support sustainability and its aspects through a Sustainable BIM Model for managing the overlapping relationship and interoperability between sustainability and BIM during the life cycle phases of a building. Hence, this methodology will be one of the future ways of enhancing the sustainability performance of buildings and using BIM tools to monitor building performance that can be employed in proper scenarios to achieve maximum benefits for balancing the design and building performance as a sustainable BIM Model. Besides, the delay problem for the real implementation of sustainability assessment systems will be solved.

The overlap potentials between the two concepts have remained the use of BIM for modelling a project, but after the Sustainable BIM Model is applied, other sustainability scopes will be included to retrofit and improve existing and new buildings. In addition to the proposed model will promote the renovation of existing buildings to accomplish rating systems and certifications of sustainability aspects during a shorter period. Linking BIM to sustainability or green buildings is the overall concept of the sustainable BIM model during achieving the methods of the sustainable design that can be utilized to analyze the impacts of green buildings.

Therefore, to achieve sustainable BIM Model; there are three types of requirements; also, the planning guide of BIM project execution presents a structured approach for implementing BIM platforms during a project, which includes the four stages, which the study has addressed. The six key obstacles that were demonstrated previously to integrate BIM and sustainability; these obstacles can be overcome by the proposed and deduced methodology. The sustainability aspects require a balanced manner in addressing to can achieve them in the proposed sustainable BIM model based on what the study demonstrated from the interoperability among these aspects and which cannot be performed one without the others.

The field of sustainability will continue to broaden in terms of views in achieving it by the possible tools, mechanisms, and modern progress and each researcher can address them from his research perspective based on experience and practice. Therefore, it is possible said that this study has sought with every effort to treat the problem of activating sustainability. Subsequently, future studies could test and check the validity of this proposed methodology to achieve a sustainable BIM model by applying in the fields of building and construction.

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