On the Exploitation of Building Information Modeling for Studying Its Possible Applications in the Construction Industry

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Abstract: - The purpose of this article is to explore two emerging trends in the Architecture, Engineering, and Construction (AEC) industry: sustainable construction (also known as green construction) and Building Information Modeling (BIM). The primary goal of this study is not to identify each topic individually; rather, this article focuses on how the use of BIM tools and techniques may improve and facilitate the process of developing sustainable green projects. Furthermore, this article introduces BIM as a new trend that paves ways for defining and presenting information needed in the design, building, and operation of built facilities. BIM may integrate the many forms of information needed in construction into a single information environment, reducing or eliminating the requirement for the various types of paper documents now in use. The paper briefly discusses the key BIM tools used in the AEC sector, with a special focus on how these tools assist users, and the obstacles of utilizing BIM. A case study is finally provided to demonstrate the time and cost reductions that BIM may accomplish in a project.

Key-Words: - Architectural engineering, BIM, rating systems, modeling, construction management, sustainable construction.

1 Introduction

1.1 Sustainability in Buildings

In a world in which energy source is becoming scarcer, sustainability has become one of the top issues for design professionals nowadays. Architects and engineers have to come up with innovative solutions to overcome those shortages of energy supplies and incessant growth of energy demands. Buildings consume around 20-40 % of the world's energy [1]. In Canada, buildings account for about 35 % of the total energy use, resulting in a great chance to achieve large-scale energy savings [2]. According to the National Energy Board [3], Canada's Energy Future 2020: Energy Supply and Demand Projections to 2050, the COVID-19 epidemic has wreaked havoc on Canada's energy system. End-use energy consumption in Canada had declined by 6 % in 2020 compared to 2019, the largest yearly decline since at least 1990. This can be attributed to the less energy used to move people and things as a result of travel restrictions and more remote work/study. As a result of decreasing demand for many products, several industries had reduced their energy use. Furthermore, as illustrated in Figure 1, commercial energy consumption had decreased due to reduced occupancy in facilities such as offices, restaurants, and schools, but household energy consumption had increased as individuals spent more time at home.

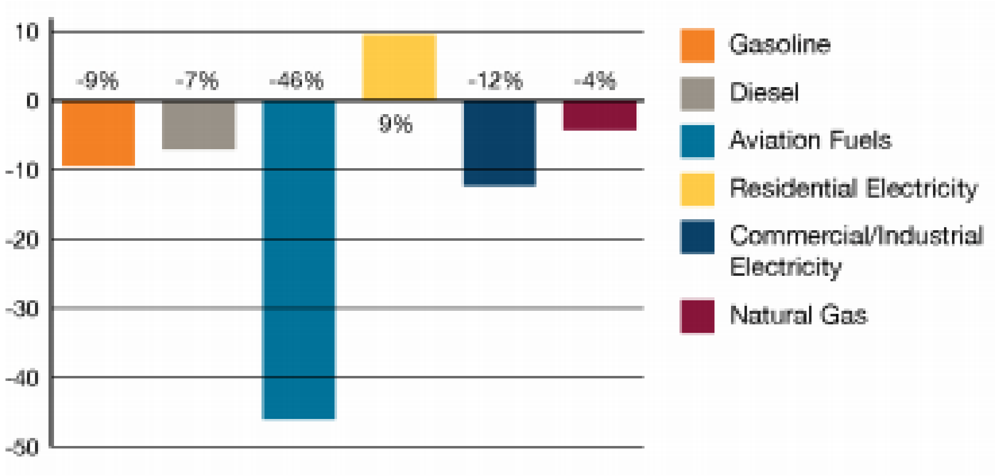

Fig.1: COVID-19 influence on the energy system in Canada.

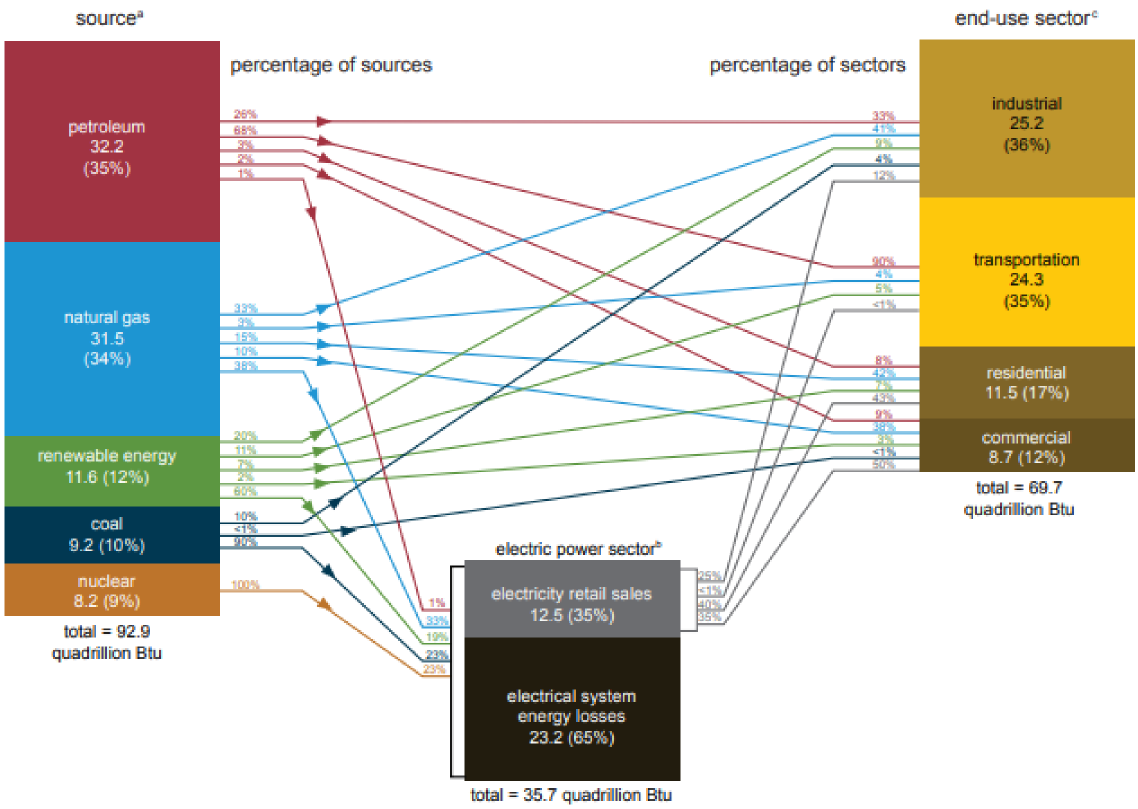

Fig.2: US energy use by source and end-use sector.

In the USA, the situation is almost similar. Buildings are responsible for around 40% of all energy use, as well as a similar percentage of greenhouse gas emissions. Therefore, lowering their energy use would not only save money in the long run but will also be a critical element of any serious climate plan [4]. According to the US Energy Information Administration [5], the total primary energy consumption was estimated to be at 93 quadrillion Btu in 2020. The energy consumption in the US by source and sector is illustrated in Figure 2. The primary energy consumption for the electric power, transportation, industrial, residential, and commercial sectors were reported to be 35.74, 24.23, 22.10, 6.54, and 4.32 quadrillion Btu. It is worth mentioning that the residential, commercial, industrial, and transportation sectors are referred to as end-use sectors because they use primary energy generated by the electric power sector.

The building industry has a major impact on community services while also improving people's quality of life and safety [6-7]. Sustainability has become a mainstream concept in the building industry as a result of rising awareness that human activities have a significant detrimental influence on the environment [8]. The World Commission on Environment and Development (WCED) defines sustainable development as “development that fulfills current demands without jeopardizing future generations' ability to satisfy their own needs” [9]. As a result, prudence must be exercised while undertaking construction projects so as not to drain available resources to the point that future generations would be unable to satisfy their demands [10].
Therefore, it is essential that sustainable practices are incorporated in the design and construction processes, in order to stabilize, if not diminish the energy consumption in buildings, particularly in the North American context. Several initiatives are being used across the globe to make buildings more sustainable and to counter undesired climate change effects. In this paper, the focus will not be given to the successful practices, but rather to the overall strategies that are being promoted in the USA and Canada. Several major rating systems and codes from around the world are going to be covered in the next sub-section, and a detailed analysis will be given for the LEED rating system that is being extensively used throughout the USA and Canada.

1.2 Rating Systems around the World

Many countries and international organizations have started rating systems for sustainable development because of the increasing demand for green buildings. There are a lot of rating systems worldwide and they are all used to rate the environmental performance of buildings. The effective use of water and energy, the reduction of greenhouse gases and carbon emissions, and the utilization of renewable resources and recyclable building materials are all parameters to consider. These objectives can be met by applying optimum design, planning, operation, and demolition strategies [11-12]. Most of the sustainability rating systems vary based on the type and size of the buildings and they merely focus on some aspects and overlook others. For instance green globe and greenship Indonesia are not efficient to evaluate the sustainability aspects of heritage buildings [13-14]. Some of these rating systems are described as follows:

Leadership in Energy and Environmental Design (USA): It is the world's most extensively utilized green building rating system. It is an example of the triple bottom line in action, helping people, the environment, and profit. This certification offers independent verification of buildings or neighborhoods, enabling the design, construction, operation, and maintenance of high-performing, resource-efficient, and cost-efficient structures.

Building Research Establishment Environmental Assessment Method (UK): It is widely used as a sustainability evaluation approach for master planning infrastructures and buildings. It acknowledges and represents the value of higher performing assets across the built environment lifespan, from new construction through in-use and renovation.

International green construction code (USA): The code council is used to regulate the construction of new and existing commercial buildings. It was proposed to help in the construction of sustainable buildings in the business and residential sectors in the USA. The target of the code is to decrease energy usage and carbon footprints, address site development and land use, preserve natural and material resources, improve indoor air quality, and support the use of energy-efficient devices, renewable energy systems, water resource conservation, rainfall collection and distribution systems.

Energy Star (USA): It is an Environmental Protection Agency (EPA) voluntary program that aids businesses and individuals make informed decisions for energy efficiency. Furthermore, it helps conserve energy, improve revenues, and strengthen the competitiveness of firms by identifying cost-effective methods to control energy usage in buildings and operations. It also promotes job creation and economic development and the transition to a clean energy economy. It is a crucial tool for combating climate change, enhancing air quality, and safeguarding public health.

Green globes (Canada): It is a rebellious building environmental design and management tool that offers an online assessment protocol, rating system and guidance for green building design, operation, and management. It is reactive, elastic and affordable, and supplies market confession of a building's environmental features through third-party realization. It has been utilized in projects of varying size, complexity, and creativity. However, when it was not widely recognized, it was often utilized for projects with low budgets. This can be attributed to the system's ability to be completed without managing the certification process by the consultant, making it an affordable certification method.

National energy code of Canada for buildings (Canada): It supplies minimum demands for the design and construction of energy-efficient buildings and covers the building casing, systems and equipment for heating, ventilating and air conditioning, service water heating, lighting, and the provision of electrical power systems and motors. It stratifies to new buildings, as well as to substantial renovations in existing ones.

Indian green building council (India): It was established in 2001 by the confederation of Indian industry. The council aims to lead a green building movement and enable India to become one of the global leaders in green buildings by 2025. The council provides a wide range of services, including the creation of new green certification services and building rating programs.

The green building assessment system (China): China set up a new building code in 2006. The concept of green building has been fundamentally adopted in commercial, public buildings, and higher market residential apartments and houses.

National Australian built environment rating system (Australia): It is a national rating system that measures the environmental performance of Australian buildings, tenancies, and homes. It measures the energy efficiency, water usage, waste management, and indoor environment quality of a building or tenancy and its effect on the environment.

Estidama (United Arab Emirates): It aims to create a new sustainability framework that will direct the current course while allowing adaptation as new understanding evolves. It enhances a new mindset for building a forward-thinking global capital to establish a special overarching framework for measuring sustainability performance beyond the usual planning and construction phases.

LiderA (Portugal): It is the Portuguese acronym of lead for the environment in search of sustainability construction. It is the designation of a Portuguese voluntary system that endeavors efficient and integrated support of the evaluation and certification process of the sustainable built environments. LiderA through its principles and criteria permits the support of development projects that demands to ensure sustainability and the request for product sustainability in built environments (e.g., buildings, urban areas, projects, materials, and products) from the design stage to the operation stage.

1.3 Rating What is BIM?

Building Information Modeling (BIM) is a relatively new and growing term in the Architecture, Engineering, and Construction (AEC) industry [15]. In this regard, it is acknowledged one of the most encouraging and promising concepts in architecture, engineering and construction industries in the recent few years. Since BIM is such an evolving concept, it is difficult to find only one definition for it. One of the widely-acknowledged definitions of building information model is that it is a data rich, object oriented, intelligent and parametric digital representation of the facility where views and data needed by different users can be extracted and analyzed to generate information that can be used to take decision and improve the process of delivering the facility. Moreover, a building information model carries all data and information related to the building as physical, functional characteristics and project life cycle information [16]. The definition of BIM may change based on the point of view and background of the user as follows [17]:

- From a design standpoint, BIM is described as a digital representation of a project's physical and functional features, as well as the technological method utilized to create a BIM model.
- From a construction standpoint, BIM refers to the use of computer modeling software to create and simulate construction and operating capabilities.
- From a facility management standpoint, BIM offers all of the information needed to manage a construction project after it has been occupied and until it is demolished.

In the context of this paper, the authors refer to the definition provided by the National Institute of

Building Sciences (NIBS). The NBIMS project committee defines BIM as follows: BIM is a digital representation of the physical and functional characteristics of a facility. A BIM model is a shared source of information about a facility during its lifecycle (i.e., from earliest conception to demolition), forming a reliable basis for informed decisions. A basic premise of BIM is collaboration by different stakeholders at different phases of a facility to insert, extract, update or modify information in the BIM model and support and reflect the roles of that stakeholder. A created 3D model using building information modeling is depicted in Figure 3.

Fig.3: 3D model development using BIM.

3D parametric modeling is very essential to building information modeling for three main reasons: 1) a building is composed of geometric components which are substantial to building information modeling, 2) parametric modeling provides methodologies to embed domain expertise as geometric information which facilitates the formation of rich building information model and 3) maintenance of the validity information is very crucial for revision and reuse of building information which can be maintained by imposing geometric constraints and rules. It is a common mistake to define BIM as just a 3D representation of a facility; one of the main advantages that BIM offers is the ability to view the project or what to be constructed in a 3D view. But this is just one of the many features BIM offers to its users. Other capabilities include (Popov et al., 2006): a) converting decentralized tools into more sophisticated solutions, b) using a graphical interface and process definition to manage informative data flows, c) developing a strategy for building design, construction, and facility management as early as possible, and d) providing a successful building operation in a quicker and less expensive procedure. Figure 4 shows visualization of architectural, structural and mechanical systems using building information modeling. An illustration of 3D model using BIM is shown in Figure 5.

The BIM advantages could be summarized as follows [18-19]: a) facilitating building simulation and visualization, b) making construction coordination easier, c) achieving more efficient and effective processes, d) keeping costs under control throughout the project life cycle, e) reducing costs while improving cost estimating accuracy and speed, f) avoiding conflicts which can save you up to 10% of the contract value, g) reducing the time it takes to complete a job by up to 7%, h) promoting better production quality, customer service, and lifetime data, i) reducing the number of requests for information and modifying orders to eliminate up to 40% of unplanned modifications, and j) streamlining the creation of construction documents. BIM is sometimes referred to as n-D modeling or representation of the physical and functional characteristics of a facility [20-21]. BIM allows its users to add time as a fourth dimension to the 3D models, also a fifth dimension (i.e., cost) can be added. These dimensions will be further discussed in more detail in the BIM tools of this paper. BIM is also referred to as a database-structured model, and this is true because the user can add as much information to the model as desired. The more information entered into a BIM model, the more accurate this model is and the more likely it is to the final product [22]. Industry foundation classes (IFC) is developed by International Alliance for Interoperability (IAI). IFC act as intelligent, comprehensive and universal data model of buildings. Many efforts are aiming to establish IFC a standard for information exchange in building industry [23].

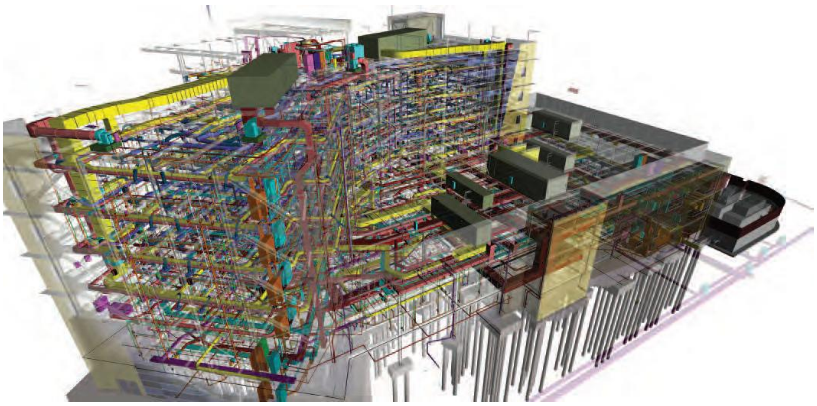

Fig.4: Ability of BIM to visualize different systems on the same screen.

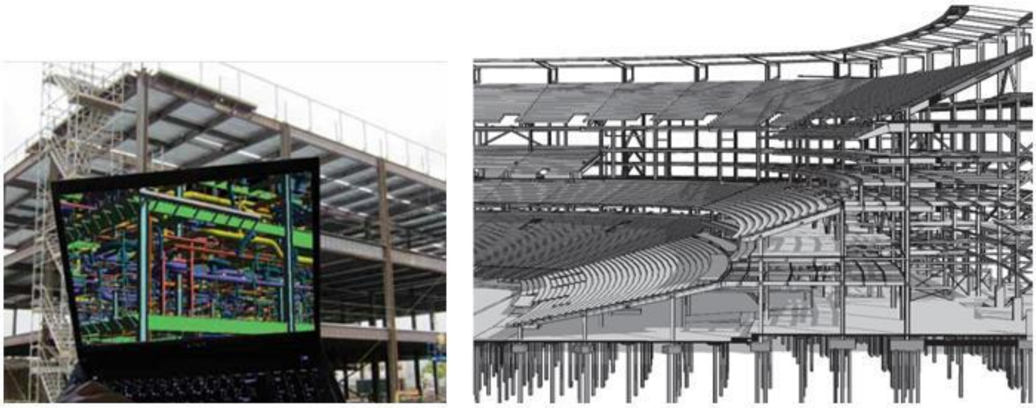

Fig.5: BIM tool for 3D visualization.

BIM is a set of tools that could be used throughout all stages of a construction process [24]. Right at the start of construction, the design stage, BIM helps in drafting the conceptual design, once approved by the concerned parties; more details (data) are added to the model to reach the detailed design. During the design process, energy calculations and analysis can be performed. During the construction stage of the project, BIM can be used to achieve 2D drawings, sections, and elevations all of which are used by the builders on site. And with the ability to add time and cost, BIM helps the project construction to be always on time and within the required budget. Even after the completion of construction, BIM acts as an as-built model and can be used by the owner or by the facility manager as a facility management tool [25-26]. An overview of the different implementations of BIM is presented in Figure 6. Azhar et al. [27] has introduced a building information modeling-based methodology for rating of buildings during design and preconstruction phases. The adopted sustainable building rating system is Leadership in Energy and Environmental Design (LEED). They applied their model to Salisbury University perdue school of business to demonstrate the features of their model. Schlueter and Thesseling [23] utilized building information models for the calculation of energy balances and exergy performance assessment to evaluate the quality of energy sources. They introduced a prototypical tool that is integrated with building information models to enable instantaneous energy and exergy calculation and graphical visualization of the resulting performance indices. Marzouk et al. [28] proposed a building information modeling-based approached to analyze building components with regards to their environmental impact. Their study tackled direct, indirect and operation emissions for six different types of gases, namely greenhouse gases, sulfur dioxide, particular matter, eutrophication particle and ozone depleting particles. It was evinced that the indirect emissions for slabs, walls and foundations were responsible for 85% to 94% of the overall greenhouse gases. This model was further extended to a fuzzy multi-objective optimization model that selected the most sustainable project alternatives with respect to cost, duration, environmental impact and energy consumed. Fuzzy set theory was exploited to address the uncertainties experienced during the construction process. Then, non-dominate sorting genetic algorithm was utilized to solve the designed multi-objective optimization problem [29].

Fig.6: Application of BIM throughout the different stages of a project.

1.4 Use of BIM

The implementation of BIM for a construction project can be beneficial to all the main players (design teams, builders, and owners) in this project. BIM provides its users with a wide set of tools that could benefit all its users. For the *design team*s (engineers or consultants), the integration of information that BIM models provide increases the efficiency of the work accomplished and reduces waste, error and improves quality. The collaboration of the different disciplines of the design teams is much easier since BIM models are composed of intelligent models, with each object having its specifications and information. For example, structural, mechanical, and electrical engineers can all enter the required data of their elements and run design scenarios to see how these systems interfere with each other and with the architectural design. BIM allows all information to be easily exchanged in one place for all parties in the design team without the need of going to search for information in plans, specifications, and schedules of other disciplines [30-31].

For the *builders* (prime contractors and sub-contractors), BIM is a very useful tool that can enable the contractors to plan their construction approach, methods, and means before they begin the actual work in a "virtual environment". Contractors can run different simulations and analyze the impact of each simulation. This will help the contractor to encounter fewer problems performing the job on the actual field, save time, reduce rework, produce a higher quality of work with less cost, and thus increasing profit. BIM also allows the contractor to add a fourth dimension (i.e., time) to the BIM model giving the contractor a powerful tool for planning and scheduling functions. A 4D model helps the contractor to monitor the project to keep the project on track and consequently deliver the project on time. Also, BIM enables the contractor to add a fifth dimension (i.e., cost estimation) to the BIM model. Since every item in the model is specified, estimators and surveyors can use BIM for exact quantity takeoffs. The design and the estimate are connected in such a way that any cost impacts associated with changes in the design can be seen immediately and thus enabling the contractor not to run over the estimated budget for the project [32-33].

For the *owners* (developers and facility managers), BIM is useful as it gives a visualization of how the project is going to look before construction begins. Any changes or modifications the owner demands can now be done in an early stage of the project, eliminating the risk of change after construction has begun. Projects modeled with BIM allow the owners to benefit from BIM even after the completion of the construction stage. Since building information models are database structured systems, BIM allows for adding as much data as required for the different equipment and systems being used in the project, these data can include information about the equipment's manufacturers, suppliers, and maintenance schedules. Owners and facility managers can benefit from these data by using BIM models to assist them as a facility management tool [34-35].

1.5 Barriers to BIM Implementation

Leśniak et al. [36] undertook attempts to identify and evaluate the causes behind the delayed adoption of BIM technology in Poland's building projects. People, and their lack of knowledge and awareness as well as their aversion to change, are the weakest link in the overall operation, which is the adoption and use of BIM technology in the building process on a wide scale. Thus, it is critical to implement preventive measures such as BIM technology training, courses, and studies to improve people's knowledge, and, above all, to demonstrate the benefits that can be realized by implementing BIM technology, particularly for small and medium-sized construction firms. Sriyolja et al. [37] conducted a systematic analysis of the most important obstacles that hinder BIM implementation. The primary limitation in deploying BIM was discovered to be the expense of purchasing BIM software, replacing equipment, and training of personnel.

The second most significant impediment to BIM implementation was discovered to be the law. Because no regulations were requiring the use of BIM on a project-by-project basis, it was rarely employed. Besides, since the work contract lacked legal clarity, the usage of BIM was deemed unnecessary. The second barrier to BIM implementation was demand. BIM was not yet ready for usage in the construction industry. Because of the ambiguity around the immediate advantages of BIM, particularly during the planning stage, demand for BIM is currently insufficient. The unwillingness to adapt stemmed from a cultural character that did not want to leave its comfort zone. For construction companies, reluctance to initiate new operations or educate employees was a major roadblock. Because of the social environment's shared culture, it was difficult for organizations to implement the new paradigm due to social opposition. Interoperability, on the other hand, made this barrier much more difficult to overcome. Process, management, awareness, expert, project scale, technology, skills, training, contract, and standard were regarded critical enough to be highlighted as part of the major obstacles to BIM adoption.

2 LITERATURE REVIEW

This section delineates in-depth the possible implementations of building information modeling in construction industry.

2.1 BIM Tools

The following section describes in more detail some of the various tools and benefits of using and implementing BIM for a project. These benefits cannot be achieved using the traditional two-dimensional drafting software.

2.2 Design Visualization

One of the most obvious uses of BIM for all the parties involved in constructing a project is the ability to view the project in a 3D view. Visualizing how a project will look just from 2D drawings is sometimes not enough. In a 3D view, BIM can present the project in a more detailed and more realistic fashion. Also, simulations can be run to conduct analyses regarding alternative approaches to both design and construction (see Figures 7, 8 and 9). The 3D tool in BIM gives the users the ability to examine and walk through the buildings in a virtual environment to have a feeling of how the project will look after construction [38]. Thanks to this tool, any changes or modifications the owner or the designer see necessary, can now be modified in this virtual environment, eliminating the risks and costs of performing this change during or after the construction.

Fig.7: Architectural model using BIM.

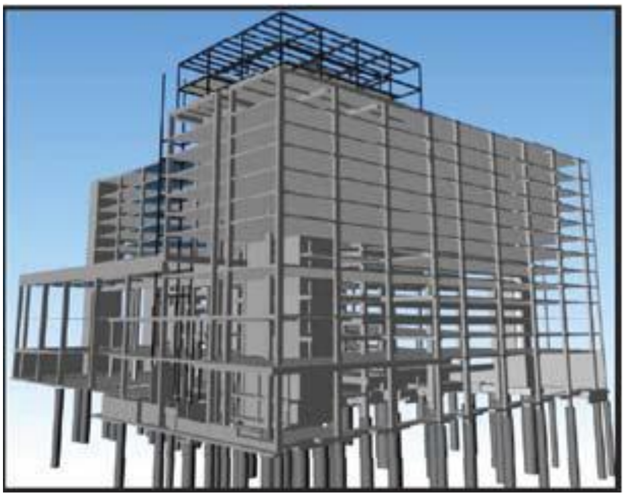

Fig.8: Structural model using BIM.

Fig.9: Plumbing model using BIM.

2.3 4D - Scheduling and Sequencing

In a traditional way of construction, there exist 2D drawings that comprise information about the materials and equipment being used, their quantities, and their locations. These are usually CAD files that can only be viewed by programs (e.g., AutoCAD). On the other hand, there also exists a plan and schedule for the project, which can only be viewed by certain software (like primavera or Microsoft project). However, the project plan and 2D drawings are not connected by any means. BIM adds a fourth dimension, time, to the 3D model which gives the ability to show the building in a 3D view while previewing the project schedule on the same screen. Using BIM, the schedule activities are connected to their graphical representation on the 3D model. Adding time to the 3D model helps everyone involved in the project to visualize the schedule and helps to monitor the project to always be on track (see Figure 10). Nusen et al. [39] integrated building information modeling and multi-objective genetic algorithm for planning of construction renovation project. The presented model contained modules for computing construction time, construction cost and resource fluctuation utilization. A 4D model was constructed to connect the 3D model and project schedule. Multi-objective genetic algorithm was deployed to schedule the project based on minimizing project time, project cost and work utilization fluctuation.

2.4 5D – Cost Estimating

Cost is a fifth dimension that can be added to a design model using BIM. All the information necessary to perform cost estimation for a project are entered into the project's BIM database, these information include quantities, lengths, heights, widths, etc. for all the materials and building components in the BIM model. These data can then be connected to a cost database to create an estimate of the project's cost. The main advantage is that the cost database is always connected to the BIM model, meaning that any change in the quantity of an object in the BIM model will directly be reflected in the cost database. The fifth dimension that the building information model can add to a project helps the project to be designed within the required budget (see Figure 11). Fazeli et al. [40] presented a building information modeling-based approach for computing construction costs of buildings. An automated tool was designed to facilitate the linkage between cost estimation standards and material takeoff. It was showed the proposed approach could reduce the time consumed in the cost estimation process. Le et al. [41] introduced an integrated model that exploited the use of building information modeling to estimate construction costs of buildings. The proposed model involved four main modules which were: relational database management, visualization, cost estimation and report generation. The automated quantity surveying and cost estimation processes were facilitated using Dynamo and Python programming languages. It was urged that the presented workflow could reduce human errors and time of cost estimation

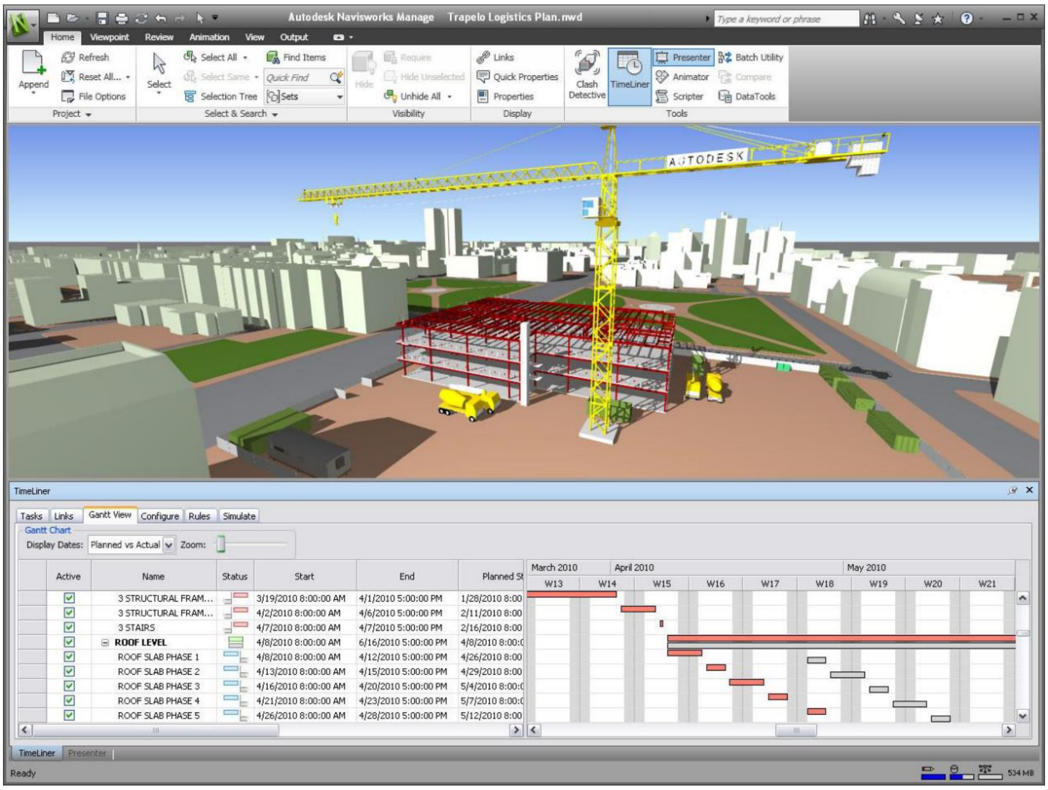

Fig.10: Incorporation of time as a fourth dimension into the 3D model.

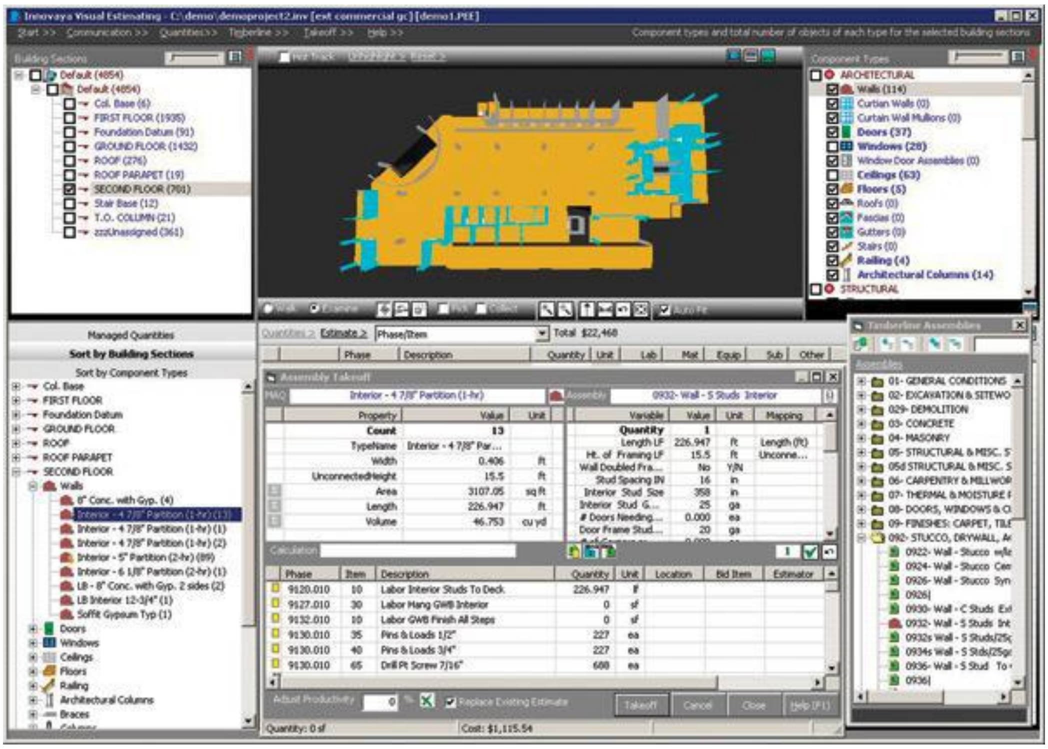

Fig.11: Addition of cost as a fifth dimension to the 3D model.

2.5 Systems Coordination

The traditional two-dimensional plans represent each system (HVAC, Electrical, Structural, etc.) in a building separately with no interconnection between these systems. With a lack of coordination between the engineers of different disciplines, Clashes are a very common problem usually faced by the builders on site. One of the most important uses of BIM by contractors today is to perform clash detection. In a 3D model, identifying the areas where systems mistakenly interfere with each other is much easier. BIM allows multiple systems to be viewed together on the same screen, this just by looking at the model, for example, an electrical engineer might notice that a cable tray is running into an HVAC duct. Also, BIM models can be developed to automatically detect clashes. Clashes are problems that would best be addressed before the actual construction would start. Clash detections enabled by BIM can check the interfaces between equipment, fixtures, pipes, ducts, conduits, structural members, and architectural features (see Figure 12). It has been papered that contractors that implement BIM tools have discovered and resolved thousands of conflicts by using BIM, which not only saved money but rework and time as well. Also, it was papered that field-related questions and requests for information (RFIs) have decreased by as much as 80 percent on projects utilizing BIM [42]. Hu et al. [43] introduced time dependent structural analysis methodology that integrates building information model with 4D technology. The introduced methodology presents a structural analysis method which generates structural geometry, resistance model and loading conditions in the presence of interlink with schedule information, architectural model and material properties. Moreover, this methodology improves safety during dynamic simulation of construction processes.

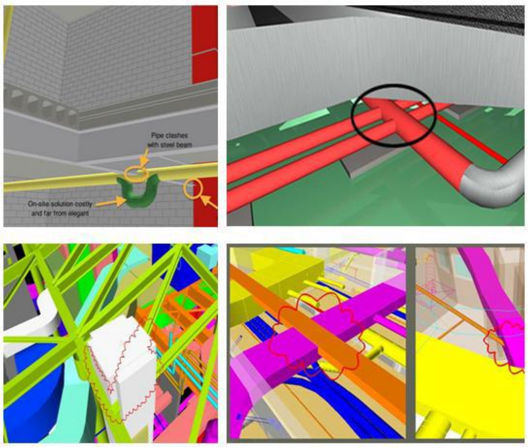

Fig.12: Clash detection using BIM.

2.6 Site Planning and Site Utilization

At the beginning of any construction project, it is necessary to study the construction site for the mobilization process. The locations of temporary site offices, storage areas, cranes, and routes for trucks and heavy equipment can be visualized and chosen using BIM. Different locations and scenarios can be performed to come out with the most efficient locations. BIM can be used as a powerful tool to ease the process of site planning (see Figure 13). Shen et al. [44] presented a building information modeling-based user activity simulation and evaluation method (UASEM). This method improves the designer-user communication. Moreover, it helps the user to identify their activities in new buildings and simulate these activities based on building information modeling. Getuli et al. [45] introduced a BIM-based model that used immersive virtual reality technology for construction workspace planning. It was urged that a clash existed between workspaces and paths designed by planners. It was also illustrated that supply chain of construction projects needs more study and analysis due to its complexity.

Fig.13: Application of choosing the right location for a tower crane.

2.7 Integration of Subcontractors and Suppliers Data

The use of building information modeling is not just used by engineering firms and construction companies only. Some suppliers have also chosen BIM to build models of their various equipment or products. Suppliers and sub-contractor add all the required and necessary information to these models as, fabrication details and installation methods and are ready to be added to any BIM model. Once a supplier, for example, an HVAC equipment supplier, is awarded to supply equipment for a project, the BIM models of the air handling units and their ducts can easily be emerged to the project's BIM database. After the supplier's data has been added to the project's database, analysis and system reviews can be done easily. This tool that BIM provides saves both time and money (see Figures 14 and 15).

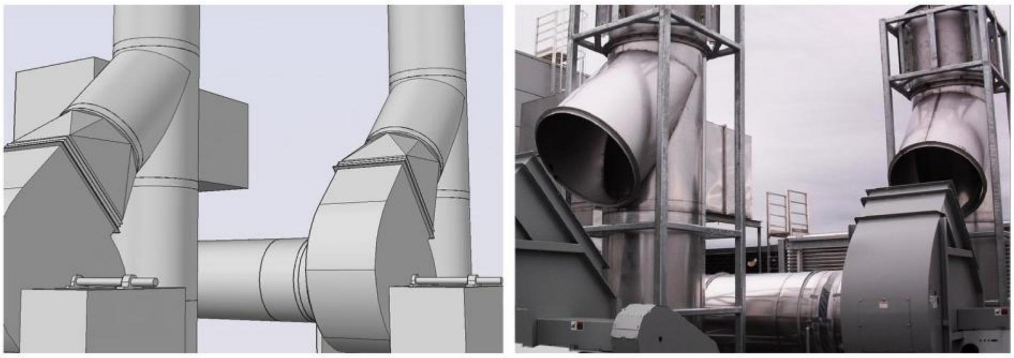

Fig.14: Clash detection using BIM.

Fig.15: Additional illustration for the integration of suppliers' models into the project database.

3 Model Development

3.1 BIM in Canada

The Institute for BIM in Canada (IBC) leads and facilitates the coordinated use of Building Information Modeling (BIM) in the design, construction, and management of the Canadian built environment. Its founding partner organizations represent specific industry sectors that have a keen interest in seeing BIM implemented in a way, and at a pace, that enables the primary stakeholders to understand their roles and responsibilities and to assess their capacity to participate in this process. IBC's priorities include an awareness program, a practice manual, a bibliography of useful resources, and a full environmental scan/assessment on the use of BIM in Canada and internationally." The mission of IBC as stated on their website www.ibc-bim.ca is to "Act as the authoritative voice of BIM in Canada" The objective of IBC as stated on their website is as follows:

- To endorse, develop and maintain Open BIM Standards for the Canadian market through the
- Canadian Chapter of building Smart-International.
- To define collaborative approaches and solutions between stakeholders in the BIM environment.
- To develop and recommend "best practices" policies, tools, and procedures to support BIM utilization.

- To educate the industry about trends and developments relative to BIM in Canada, and about the pace of adoption that is increasing steadily in the Canadian built environment.
- To communicate its activities to the industry at large.

3.2 Benefits of BIM – A Case Study

BIM is claimed to benefit its users by saving time and money. In this section, a case study [18] will be introduced to illustrate the savings in cost and time that are achieved when developing and implementing a BIM model for an actual project. The main focus of this case study is to show how BIM can be used in clash detection. Below is a summary of the facts and figures of the case study. Table 1 shows description of case study in United States of America. The clashes between different systems constructed using BIM are reported in Table 2.

Table 1: Case study facts and Figures.

Project Name	Hilton Aquarium
Project's Location	Atlanta, Georgia, USA
Description	484,000 SF hotel and parking structure
Project Cost	$ 46 Million
BIM Scope	Design coordination, clash detection, and work sequencing
BIM Cost	$90,000 - 0.2% of project budget

Table 2: Clashes detected using BIM summary.

Collision Phase	Collisions	Estimated Cost Avoided	Estimated Crew Hours		Coordination Date
100% Design Development Conflicts	55	$124,500	NIC		*June 30, 2006*
Construction (MEP Collisions)					
Basement	41	$21,211	50	hrs	*March 28, 2007*
Level 1	51	$34,714	79	hrs	*April 3, 2007*
Level 2	49	$23,250	57	hrs	*April 3, 2007*
Level 3	72	$40,187	86	hrs	*April12, 2007*
Level 4	28	$35,276	68	hrs	*May 14, 2007*
Level 5	42	$43,351	88	hrs	*May 29, 2007*
Level 6	70	$57,735	112	hrs	*June 19, 2007*
Level 7	83	$78,898	162	hrs	*April 12, 2007*
Level 8	29	$37,397	74	hrs	*July 3, 2007*
Level 9	30	$37,397	74	hrs	*July 3, 2007*
Level 10	31	$33,546	67	hrs	*July 5, 2007*
Level 11	30	$45,144	75	hrs	*July 5, 2007*
Level 12	28	$36,589	72	hrs	*July 5, 2007*
Level 13	34	$38,557	77	hrs	*July 13, 2007*
Level 14	1	$484	1	hrs	*July 13, 2007*
Level 15	1	$484	1	hrs	*July 13, 2007*
Subtotal Construction Labor	590	$564,220	1143	hrs	
20% MEP Material Value		$112,844			
Subtotal Cost Avoidance		**$801,565**			
Deduct 75% assumed resolved via conventional methods		($601,173)			
Net Adjusted Direct Cost Avoidance		**$200,392**			

All clashes have been quantified, these would have been the cost of resolving these clashes if they happened on site. An assumption that 75% of these clashes would have been resolved by traditional means resulting in a net savings of $200,000 in money and almost 1,150 hours of man-hours. Knowing that the original amount invested in BIM was $90,000, this shows how BIM implementation for a project can yield savings of more than 220%.

3.3 Future of BIM – Cloud Computing

The main reason why any architectural, engineering, or construction industry uses BIM is the ability of BIM to share, integrate and manage the entire project's data between the different parties involved. BIM acts as one source for all the data and information that can be accessed by everybody working on the project. However, the recent BIM software being used by the AEC industries such as Autodesk Architecture are Bentley Architecture are all desktop applications and are therefore site related, meaning that they are standalone systems. The problem occurs when one party, for example, the sub-contractor, wants to view or update the information to the model but is in a far location not connected to the software's network. Using this system architecture, obtaining information or updates regarding the project from a far location or another site is difficult. The fact that these softwares run as standalone system frameworks restricts and puts limitations on how the information is being shared and from where. The paper Applying Cloud Computing Technology to BIM Visualization and Manipulation describes that recently the framework of applications is now moving from applications that are site related, or "Client Server" applications to "Host-Based" applications which is also referred to as "Cloud Computing" [46-50]. This paper introduces the idea of Software as a Service (SaaS), in which all the BIM model data will be saved on a server and can be accessed through the web. Cloud computing removes the limitations and restrictions of where the BIM data can be shared from. With the expected growth increase of BIM over the next few years, similar growth is expected to Cloud Computing as well due to its great benefits (see Figure 16).

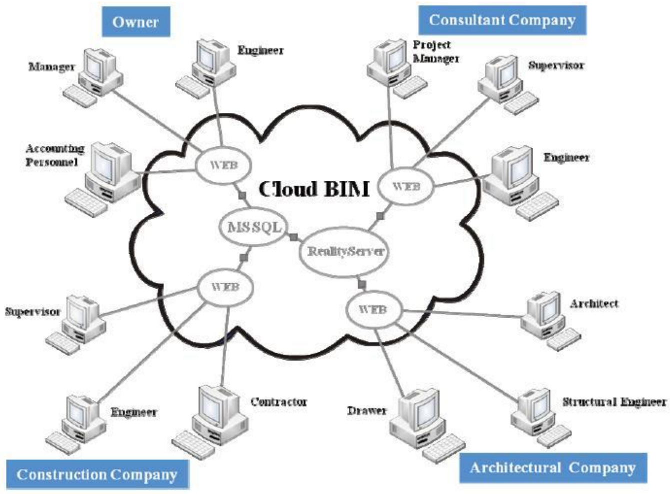

Fig.16: Cloud computing system architecture.

4 Conclusion

According to recent studies, the BIM industry was quickly growing, and some analysts attributed BIM development in the coming years to the growing need for sustainable design. This article discussed the fundamental notion of BIM, its primary benefits, and the many tools that BIM provides to its users. The concept of sustainable or green design, as well as the growing demand for such designs and the many rating systems used across the world, were then discussed. The focus of this study was on LEED certification, which is one of the most widely used rating systems. Finally, the relationship between BIM and the LEED certification process was discussed in greater depth, and a demonstration of BIM and LEED collaboration was extensively explained in two case studies.

References:

[1] Pérez-Lombard, L., Ortiz, J., & Pout, C. (2008). A review on buildings energy consumption information. *Energy and buildings*, *40*(3), 394-398.

[2] Hicks, A. G. (2018). Reducing Energy Consumption in Residential Buildings: The Impacts of Occupant Behaviour and Engaging Control Systems (Doctoral dissertation, Carleton University).

[3] National Energy Board (2020). Canada's Energy Future 2020: Energy Supply and Demand Projections to 2050. https://www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2020/canada-energy-futures-2020.pdf (accessed 3 August 2021).

[4] Alliance to Save Energy (2021). Buildings. https://www.ase.org/categories/buildings (accessed 3 August 2021).
[5] EIA (2021). U.S. energy facts explained. https://www.eia.gov/energyexplained/us-energy-facts/ (accessed 3 August 2021).
[6] Manzoor, B., Othman, I., Gardezi, S. S. S., & Harirchian, E. (2021). Strategies for adopting building information modeling (Bim) in sustainable building projects—A case of Malaysia. *Buildings*, *11*(6), 1–14.
[7] Fearnside, P. M. (2018). Challenges for sustainable development in Brazilian Amazonia. *Sustainable Development*, *26*(2), 141–149.
[8] Khan, H. H., Malik, M. N., Zafar, R., Goni, F. A., Chofreh, A. G., Klemeš, J. J., & Alotaibi, Y. (2020). Challenges for sustainable smart city development: A conceptual framework. *Sustainable Development*, *28*(5), 1507–1518.
[9] WCED. (1987). *Report of the World Commission on Environment and Development: Our Common Future: Our Common. Future*, 1-300.
[10] Manzoor, B., Othman, I., & Manzoor, M. (2021). Evaluating the critical safety factors causing accidents in high-rise building projects. *Ain Shams Engineering Journal*, 1-8.
[11] Elattar, S. M. (2014). Towards The Adaptation of Green Building Material Systems to the Egyptian Environment. *Journal of Asian Scientific Research*, *4*(6), 260-269.
[12] Assaf, A., & Nour, M. (2015). Potential of Energy and Water Efficiency Improvement in Abu Dhabi's Building Sector – Analysis of Estidama Pearl Rating System. *Renewable Energy*, *82*, 100-107.
[13] Al-Sakkaf, A., Mohammed Abdelkader, E., El-Zahab, S., Bagchi, A., Zayed, T. & Elshaboury, N. (2021). An Integrated Multi-Criteria Decision Making Model For Evaluating Sustainability Rating Systems. *CSCE Annual Conference 2021*, 26-29 May.
[14] Al-Sakkaf, A., Zayed, T., Bagchi, A., & Mohammed Abdelkader, E. (2019). Sustainability Rating Tool and Rehabilitation Model For Heritage Buildings. *CSCE Annual Conference 2019*, Laval, Canada, 12-15 June, 1-11.
[15] Cha, H. S., & Jiang, S. (2020). Special Issue on BIM in the Construction Industry. *Applied Sciences*, 10(2), 1-19.
[16] Azhar, S., Nadeem, A., Mok, J. Y. N., & Leung, B. H. Y. (2008). Building Information Modeling (BIM): A New Paradigm for Visual Interactive Modeling and Simulation for Construction Projects. *First International Conference on Construction in Developing Countries (ICCIDC-I)*, 435–446.
[17] Abbasnejad, B., & Moud, H. (2013). BIM and Basic Challenges Associated with its Definitions, Interpretations and Expectations. *International Journal of Engineering Research and Applications*, *3*(2), 287-294.
[18] Azhar, S. (2011). Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. *Leadership and Management in Engineering*, *11*(3), 1-12.
[19] Sun, C., Jiang, S., Skibniewski, M., Man, Q., & Shen, L. (2017). A Literature Review of the Factors Limiting the Application of BIM in the Construction Industry. *Technological and Economic Development of Economy*, *23*(5), 764-779.
[20] Matusova, D., & Bartošová, V. Utilization the Process BIM–Building Information Modeling in Facility Management. *International Conference on Applied Economics*, 42-436.
[21] Borrmann, A., König, M., Koch, C., & Beetz, J. (2018). Building information modeling: Why? What? How?. *Building information modeling*, 1-24.
[22] Kjartansdóttir, I. B., Mordue, S., Nowak, P., Philp, D., & Snæbjörnsson, J. T. (2017). *Building Information Modelling-BIM*. Faculty of Warsaw University of Technology.
[23] Schlueter, A., & Thesseling, F. (2009). Building information model based energy / exergy performance assessment in early design stages. *Automation in Construction*, *18*(2), 153–163.
[24] Li, Z.; Quan, S.J., & Yang, P.P.-J. (2016). Energy performance simulation for planning a low carbon neighborhood urban district: A case study in the city of Macau. *Habitat International*, *53*, 206–214.
[25] Arayici, Y., Egbu, C., & Coates, P. (2012). Building Information Modelling (BIM) Implementation and Remote Construction Projects: Issues, Challenges, and Critiques. *Journal of Information Technology in Construction*, 1-18.
[26] Mohamed, A. E. (2019). *The implementation of building information modeling (BIM) towards sustainable construction industry in Egypt "The pre-construction phase"*. American University in Cairo, Egypt.
[27] Azhar, S., Carlton, W. A., Olsen, D., & Ahmad, I. (2011). Building information modeling for sustainable design and LEED ®

rating analysis. *Automation in Construction*, *20*(2), 217–224.

[28] Marzouk, M., Mohammed Abdelkader, E., & Al-Gahtani, K. (2017). Building Information Modeling-based Model for Calculating Direct and Indirect Emissions in Construction Projects. *Journal of Cleaner Production*, *152*, 351-363.

[29] Marzouk, M. and Mohammed Abdelkader, E. (2020). A hybrid fuzzy-optimization method for modeling construction emissions. *Decision Science Letters*, *9*(1), 1-20.

[30] Harding, J., Suresh, S., Renukappa, S., & Mushatat, S. (2014). Design Teams in Achieving BREEAM Accreditation ?. *Journal of Construction Engineering,* Article ID 390158, 8 pages.

[31] Chang, Y. F., & Shih, S. G. (2013). BIM-based computer-aided architectural design. *Computer-Aided Design and Applications*, *10*(1), 97–109.

[32] Rathnasinghe, A. P., Kulatunga, U., Jayasena, H. S., & Wijewickrama, M. K. C. S. (2020). Information flows in a BIM enabled construction project: developing an information flow model. *Intelligent Buildings International*, 1–17.

[33] Arensman, D. B., & Ozbek, M. E. (2012). Building Information Modeling and Potential Legal Issues. *International Journal of Construction Education and Research*, *8*(2), 146–156.

[34] Aziz, N. D., Nawawi, A. H., & Ariff, N. R. M. (2016). Building Information Modelling (BIM) in Facilities Management: Opportunities to be Considered by Facility Managers. *Procedia - Social and Behavioral Sciences*, *234*, 353–362.

[35] Dixit, M. K., Venkatraj, V., Ostadalimakhmalbaf, M., Pariafsai, F., & Lavy, S. (2019). Integration of facility management and building information modeling (BIM): A review of key issues and challenges. *Facilities*, *37*(7–8), 455–483.

[36] Leśniak, A., Górka, M., & Skrzypczak, I. (2021). Barriers to BIM Implementation in Architecture, Construction, and Engineering Projects-The Polish Study. *Energies*, 14(8), 1-20.

[37] Sriyolja, Z., Harwin, N., & Yahya, K. (2021). Barriers to Implement Building Information Modeling (BIM) in Construction Industry: A Critical Review. *IOP Conference Series: Earth and Environmental Science*, 1-9.

[38] Kong, S. W. R., Lau, L. T., Wong, S. Y., & Phan, D. T. (2020). A study on effectiveness of Building Information Modelling (BIM) on the Malaysian construction industry. *IIOP Conference Series: Materials Science and Engineering*, 1-9.

[39] Nusen, P., Boonyung, W., Nusen, S., Panuwatwanich, K., Champrasert, P., & Kaewmoracharoen, M. (2021). Construction planning and scheduling of a renovation project using bim-based multi-objective genetic algorithm. *Applied Sciences*, *11*(11), 1-18.

[40] Fazeli, A., Dashti, M. S., Jalaei, F., & Khanzadi, M. (2020). An integrated BIM-based approach for cost estimation in construction projects. *Engineering, Construction and Architectural Management*, 1-27.

[41] Le, H., Likhitruangsilp, V., & Yabuki, N. (2021). A BIM-database-integrated system for construction cost estimation. ASEAN Engineering Journal, *11*(1), 45–59.

[42] Jackson, B. J. (2010). Construction Management JumpStart. Wiley Publishing, Inc.

[43] Hu, Z., Zhang, J., & Deng, Z. (2008). Construction Process Simulation and Safety Analysis Based on Building Information Model and 4D Technology. *Tsinghua Science and Technology*, *13*, 266–272.

[44] Shen, W., Shen, Q., & Sun, Q. (2012). Building Information Modeling-based user activity simulation and evaluation method for improving designer-user communications. *Automation in Construction*, *21*(1), 148–160.

[45] Getuli, V., Capone, P., Bruttini, A., & Isaac, S. (2020). BIM-based immersive Virtual Reality for construction workspace planning: A safety-oriented approach. *Automation in Construction*, *114*, 1-20.

[46] Elahi, B., Malik, A. W., Rahman, A. U., & Khan, M. A. (2020). Toward scalable cloud data center simulation using high-level architecture. *Software - Practice and Experience*, *50*(6), 827–843.

[47] Sun, Y., & Li, S. (2021). A systematic review of the research framework and evolution of smart homes based on the internet of things. *Telecommunication Systems*, *77*(3), 597–623.

[48] Al-Sakkaf, A., & Ahmed, R. (2019). Applicability of BIM in heritage buildings: a critical review. *International Journal of Digital Innovation in the Built Environment (IJDIBE)*, *8*(2), 20-37.

[49] Al-Sakkaf, A., Zayed, T., & Bagchi, A. (2020). A sustainability based framework for evaluating the heritage buildings. *International Journal of Energy Optimization and Engineering (IJEOE)*, *9*(2), 49-73.

[50] Al-Sakkaf, A., Zayed, T., Bagchi, A., Mahmoud, S., & Pickup, D. (2020). Development of a sustainability rating tool for heritage buildings: future implications. *Smart and Sustainable Built Environment*.

Contribution of individual authors to the creation of a scientific article (ghostwriting policy)

Abobakr Al-Sakkaf analyzed the findings and the results of the models and aided in writing the article. Ghasan Alfalah developed the methodology and concept and aided in writing the article. Eslam Mohammed Abdelkader aided in developing the methodology and concept and writing the article. Nehal Elshaboury helped in writing and editing.