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Review

Review of the Building Information Modelling (BIM) Implementation in the Context of Building Energy Assessment

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Abstract: In recent years, many researchers across the world have addressed the implementation of Building Information Modelling (BIM) in the energy assessment of the built environment. However, several potential issues still need to be resolved in order to utilise the benefits provided by BIM to a maximum degree. To fill this gap, a systematic literature review is conducted in this study to critically investigate the utilisation of BIM tools in energy assessment. To achieve the above-mentioned objective, after shortlisting the relevant papers published hitherto, using keyword searching, a systematic review was undertaken, including the application of BIM in the contexts of different countries, types of BIM tools, BIM and Life Cycle Assessment (LCA) integration, energy affiliations, stakeholders' involvement and their roles, uncertainty, and sensitivity analysis. The outcomes show the most widely used and effective BIM tools in different types of construction projects in various countries. The review of the literature clearly shows that BIM tools can effectively be used in the assessment of energy performance of buildings. The article gives insight to engineers, architecture, and decision makers to carefully select appropriate BIM tools in terms of energy assessment.

Keywords: energy efficiency; energy assessment; sustainability; BIM-LCA; BIM tools

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1. Introduction

The construction industry is one of the major consumers of natural resources [1]. The Resource Conservation Alliance suggests that the construction sector is responsible for nearly 50% of the world's natural resource extraction and consumption [2]. In addition, nearly half of the annual energy use at the global level is attributed to the built environment [3]. The construction industry has posed significant negative impacts on the environment not only in terms of depletion of natural resources, but also in terms of overall pollution and global warming [4].

To mitigate these impacts, various sustainability related practices and measures are currently being introduced within contemporary built environment studies and legislation. Among them are concepts and practices addressing energy efficiency of buildings, such as zero energy buildings (ZEBs) [5], green buildings (GBs) [6], life cycle assessment (LCA) [7], and sustainable retrofitting and renovation of old buildings [8]. These concepts and practices are further enhanced by the integration of Building Information Modelling (BIM) tools. BIM is defined as the parametric representation of the physical and functional features of a construction project, making the information management of such projects feasible [9]. In light of this, the utilisation of BIM has incurred benefits to the concerned construction/project managers in the following ways: optimal layout planning of construction equipment on construction site [10], the inputs to mathematical modelling to solve a construction-related problem [11], coordination of MEP-related issues [12], facilitating the structural inspection of buildings facilities [13,14], and so forth. Having said that, according to [15], the exploitation of BIM has surpassed the common modelling of construction projects (i.e., 3D), including 4D (i.e., construction schedule and planning), 5D (i.e., construction cost estimating and planning), 6D (i.e., environment-related issues), and 7D (i.e., operations and maintenance).

Zhang et al. [16] examined sustainable practices that could be used by different stakeholders interested in applying sustainability measures for construction processes, and proposed a sustainability assessment tool based on a BIM platform. The BIM platform was found to be very useful in analysing the real-time energy use and sustainability-related data, whichare used in making decisions and finding solutions to issues that may arise during construction and operation stages [17]. Ajayi et al. [18] proposed a BIM-enhanced life cycle assessment methodology to understand the impact of different material types and their characteristics on long-term performance of a project. The assessment was carried out by breaking down the energy use life-cycle into four main phases (namely, (1) goal setting, (2) inventory analysis, (3) impact assessment, and (4) interpretation) that were afterwards incorporated into the established framework to enhance sustainability. BIM methodology creates a collaborative way to explain the relationships between key components of the construction process. It should be utilised throughout the construction and operational phases if sustainability and energy efficiency are the aim [16].

In terms of BIM application, there are several tools and software that are currently being used. Numerous studies have found that application of BIM software includes the selection of the most appropriate software that can address the scope of the work effectively, thus producing effective solutions in terms of energy efficiency. A study by Mahmud et al. [19] classified two hundred softwares based on domain, zone, and layer within the "CEN-CENELEC-ETSI Smart Grid Reference Architecture". Rezaee et al. [20] proposed an energy model that estimated the energy performance of different design alternatives in a specific design decision scenario.

Taha et al. [21] evaluated the impact of renewable energy technologies integration in educational buildings in Iraq. The study found that energy efficiency in buildings achieved by the integration of photovoltaic panels and artificial lighting can be further improved by running an additional energy and daylight performance analysis, aided by the BIM-based energy simulations. In another study by Althaus et al. [22], to emphasise the impact of renovation of energy efficiency, the LCA approach was adopted to analyse the energy performance of 20 residential buildings in Zurich, and it was found that the prediction of operational energy use helps to a greater extent in achieving a higher level of energy efficiency. Theresa Innocent and Ramalingam [23] carried out real-time energy simulations of several buildings with different building envelope components and materials. The analysis helped to identify the most optimal envelope structure that provided improved indoor thermal comfort under varied climatic conditions.

Although a number of studies have been carried out in various areas related to BIM technologies and energy assessment (for example, the BIM tools selection problems [24], solar energy simulations [25] and the impact of climate conditions [26], and design parameters on energy use [27]), quality research with a concentration in these areas of study have not been conducted well yet.

This study aims to critically review the scientific publications focusing on the utilisation of BIM in the building energy assessment to capture the present-day situation and to make recommendations for the industry based on the findings. To achieve this goal, a systematic review has been carried out. Relevant publications for some selected developing and developed countries are identified to analyse the most popular and useful BIM tools that have been used for energy assessment. Additionally, this literature review shows how BIM tools can effectively help to promote energy efficiency in buildings. The outcome of this study will provide a basis and guidance for future researchers on the topic of energy efficiency assessment in buildings using BIM.

2. BIM Application for Building Energy Assessment

Energy performance assessment (EPA) is defined as an evaluation of a building's energy consumption and greenhouse gas emissions [28], which also predicts the future energy requirement. Such an analysis can be performed more precisely with the aid of BIM-based technologies [28]. BIM tools allow for adopting an integrated approach, where energy performance is assessed after specifying building geometry and systems, geographic factors, material composition, and other characteristics that help with a higher level of assessment accuracy [29]. This helps to reduce energy intake, eventually leading to savings in terms of operational costs [30]. Moreover, by adopting additional sustainability measures and practices, the maintenance costs of buildings can be further reduced, contributing to environment protection from the negative impacts of greenhouse gas emissions generated by buildings throughout their life cycle [31]. A number of studies addressed this theme. Kamaruzzaman et al. [32], for example, identified key sustainability criteria set by various energy certification schemes, such as, for example, LEED, BREEAM, GREEN MARK, GBI, etc. Di Bari et al. [33–35] investigated the ways of reducing environmental impacts and improving the overall performance of building concurrently with reducing the overall cost of operation and maintenance of buildings. They have found that this can be done by adopting the BIM-integrated LCA approach. Verichev et al. [36] and Kaoula and Bouchair [4], in turn, attempted to increase the buildings' performance by the selection of optimal building materials based on a climate sensitivity analysis. To ensure a comprehensive energy assessment, it is important to understand various types of BIM tools that are available on the given market and consider their interoperability with other tools, which can improve the overall effectiveness of adopted tools. The selection of a right BIM tool is an important step, both in terms of accuracy of results and data reliability [18].

According to Zhang et al. [16], most of the BIM software tools are currently being underutilised, leading to ineffective energy assessment of buildings. Advanced planning of the construction and operational phases is one of the most critical considerations for achieving an optimum level of energy efficiency and sustainability in general, and therefore needs to be considered while integrating BIM tools. Analysed data and other considerations must also be shown in the BIM models to receive an informative assessment to help with moving towards establishing an environmental balance [16,37]. This can be achieved by an effective selection of BIM tools, categorising their respective features, and making the quantity of tool selection more manageable [38]. Mahmud et al. [19] considered over 200 tools, based on the "CEN-CENELEC-ETSI Smart Grid Reference Architecture" document to deal with issues of complex projects, referring to the roles, domain, and hierarchy zone. The tool choice selection was set into main CAD software for a hybrid approach to achieve set targets, for example, by using eQUEST or EnergyPlus [39]. As explained earlier, these attributes need to be delivered through connected model making; the use of integrated software approaches means that the models' unique data will be utilised [40].

In terms of early design phases, the developed and analysed BIM model can lose a part of the data while being transferred into an energy simulation tool [41]. Spiridigliozzi et al. [42] recommended a few options to minimise this issue. First of all, this can be done by the integration of parametric modelling using an architectural software (e.g., Autodesk Revit) for the developing of geometric forms and using the Dynamo-visual programming plug-in for a scripting platform. This supports the BIM Revit tool when converting an IFC file to a simulation tool (e.g., EQUA IDA-ICE) for thermal evaluation [43–45]. The IFC file is one of the most widely-used models that meets the BIM International Organisation Standardisation (ISO) standard 16739-1:2018 [46]. This method was done through a residential build, which may have only required minimal specified data to begin with, creating a gap with this information. Challenges are faced with data transfer, as mapping is required between the elements [42]. The BIM model elements are identified as surfaces, but there needs to be further coordination with the thermal association in the simulation tool [47,48].

Although there were studies related to this issue, there is still room for enhancing building energy performance. For instance, the hybridisation of tools has shown some benefits; however, it suffers from the risk of data loss between the architectural drawings stage and energy performance simulations [41]. In applying the hybridisation method, stakeholders would need to have an in-depth understanding of how successful the integrated tools work together [49]. There is a wide selection of BIM tools, and due to a lack of historical data availability, stakeholders could be unaware of potential energy saving opportunities, which could be jeopardised due to poor selection [50].

3. Methodology

Facing the existing literature gap about the application of BIM to evaluate the energy efficiency in buildings, the main objective of this study is to identify the status of BIM application within developing and developed countries, as well as recognising the most efficient BIM tools in decreasing energy consumption. The goal is to identify the most popular energy and architectural BIM tolls in different types of projects within the selected country. It is also intended to investigate how the application of BIM tools can play a more effective role in analyzing and reducing the energy consumption in buildings. Therefore, the following main research questions are established:

- What is the difference in the application of a BIM tool in developing and developed countries?
- Which are the most popular energy and architectural BIM tolls?
- How can BIM tools promote energy efficiency in buildings?

To precisely answer the formulated research questions, a systematic review was performed. Figure 1 delineates the overall procedure sequences for this study. The first step presents relevant works and identifies the study gap. The next stage attempts to identify all publications in the field of BIM, with a concentration on energy assessment in buildings for some selected countries that includes developing and developed countries. The relevant publications are based on Scopus, which presents as a meta-search engine, as recommended by [51]. Surfing the database for publications, we considered the use of relevant keywords, which were: "BIM", "Building", and "energy assessment". As a result, we retrieved a significant number (657) of articles, which were then carefully reviewed (abstract and (if necessary) full text review) to select the relevant studies to the subject of the present paper. Thus, 77 articles were found to be related to the subject (as of February 2020), of which the majority are published by "Energy and Buildings", "Journal of Cleaner Production", "Sustainable Cities and Society", "Journal of Building Engineering", and "Renewable and Sustainable Energy Reviews". Except for a few studies, the majority of the articles on the subject were published in the last decade, more specifically, since 2015. This clearly shows how much effort has been invested in the adoption of BIM for energy assessment in the built environment.

All retrieved studies were then comprehensively reviewed, and the following analyses were conducted: (1) number of publications for each country, (2) identify the type of project, (3) identify the BIM tool, (4) determine if the area of application of BIM tools is either for energy assessment or architectural purpose. The last step, through literature review, investigates how BIM tools are able to promote energy efficiency in buildings. The next step is concerned with conducting a critical review of the body of existing knowledge, which leads to a compilation of the potential research stream that can be taken into account for future research.

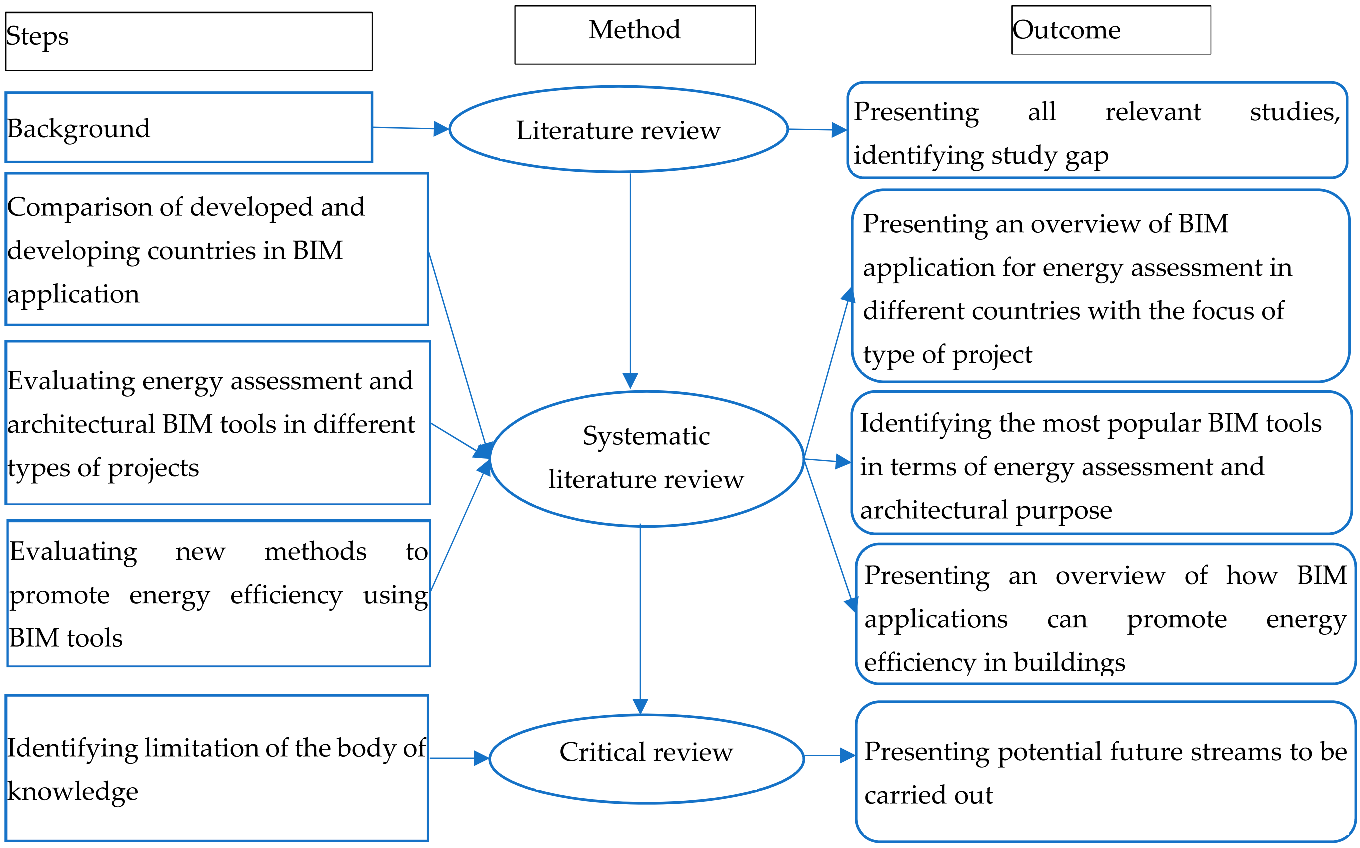

Figure 1. Methodological framework.

4. Results

4.1. BIM Application in Different Countries

Figure 2, which illustrates the number of articles (*y*-axis) published on the subject from different countries, reflects the application level of BIM tools in various countries. The figure indicates that BIM is more popular in developed countries, in contrast to developing nations. Among developed countries, the USA leads the chart and is followed by Italy. Among the reasons behind the USA's high level of application of BIM tools is the technological advancement and availability of respective resources. It should be noted that most of the currently available BIM tools in the construction market are mainly developed in the USA [52]. Another driving factor is the higher level of awareness about BIM tools among construction stakeholders [53]. According to Hamma-adama and Kouider [54], the USA has integrated BIM technologies into its education system since 2002, with at present, nearly 80% of universities and colleges delivering BIM-related modules. This shows the level of promotion of the BIM philosophy among the new generation and setting the BIM as a basic requirement of the industry. Finally, standardisation and collaboration levels within the industry made the success of the application of BIM tools possible. On one hand, the application of BIM tools has been considered as a requirement, which became possible by backing up with various standards and technical policies. Another contributing aspect to the successful implementation of BIM-related policies can be linked with working on collaborative platforms [55]. Over the last three decades, the US construction industry had a number of successful attempts to create an integrated working environment in the architecture, engineering, and construction (AEC) industry [56]. Architects, for example, highly utilise the BIM concepts in their projects, providing various stakeholders an opportunity to collaboratively work right from the design stage, and thus achieving positive outcomes at the end of a project [57].

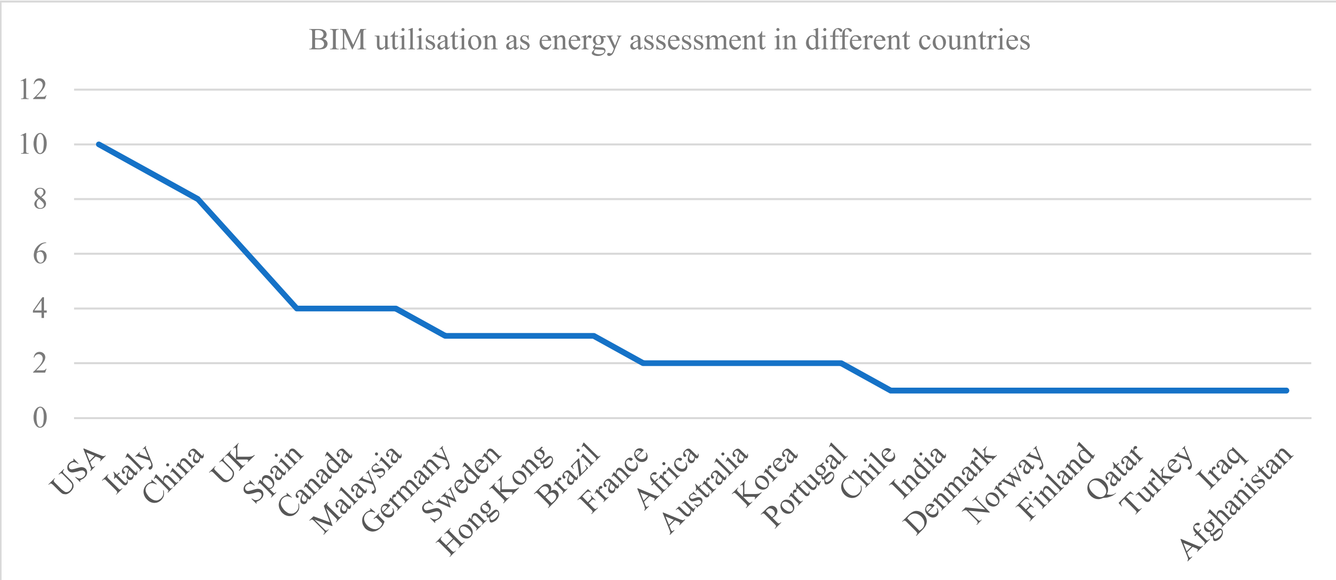

Figure 2. BIM application for energy assessment in different countries.

Figure 2 also indicates that BIM is widely used among most of the European nations, especially in the UK. Since 2011, the BIM implementation became a mandatory requirement for all government-funded projects in the UK, aiming to provide benefits to all stakeholders in terms of savings in cost, time, and resources [58]. The UK Government achieved approximately 800 million GBP savings between 2011 and 2016 by adopting the BIM implementation strategy. BIM application doubled from 31% in this period [54]. This strategy also aimed at achieving energy consumption rate decrease and minimising greenhouse gas emissions [59]. In addition, since 2011, education institutions in the UK are required to provide training of BIM tools, such as Revit, SketchUp, and Navisworks, to increase awareness and keep students updated with current industry practices [60]. At the same time, the highest levels of application of BIM tools for a developing country is reported to be in China. According to Herr and Fischer [61], in China, contractors play a crucial role in mandating the application of BIM tools. In 2013, the BIM Union developed the “Unified Standard for BIM Application” as a standard to be followed by all practitioners in the construction sector as a collaborative step taken by the Construction Industry and Science and Technology’s Ministry in China. Along with China, BIM application has grown in other developing nations, such as Malaysia, Hong Kong, Brazil, South Africa, and South Korea [62]. In Malaysia, for example, the construction authorities issued a programme in 2016, titled the “Construction Industry Transformation Programme”, aiming to achieve buildings with higher productivity and sustainability levels in the following four years [53]. This served as a driving force for increasing the integration of BIM technologies to achieve energy efficiency of buildings in Malaysia. Further, Figure 2 shows that there is a low level of application of BIM tools in Australia compared to the previously mentioned countries [62]. Although the application of BIM tools in Australia is at its minimal level, the country is working on promoting the BIM philosophy. For example, the National BIM guide by NATSPEC, a national not-for-profit organisation, was developed to provide various guidelines set by the innovation sector [63]. BuildingSmart is another initiative contributing to raising awareness around BIM integration in Australia by promoting the novel concept of Open BIM [62]. Singapore is another state from that region and is among the leading nations in terms of BIM implementation. However, there were no articles found where BIM is used as a tool for energy assessment. This statement does not challenge Singapore’s contribution to BIM application at a wider context, as this study reviewed the subject on the basis of the data obtained solely using the Scopus database.

4.2. BIM Utilisation in Different Areas of Construction Projects in Various Countries

Figure 3 shows BIM implementation in terms of energy efficiency in different types of projects in various countries. The graph indicates that, for example, the USA utilises BIM tools in almost every aspect of infrastructure projects, which is a result of the effective implementation of respective policies and frameworks introduced by the government [64]. According to Liu et al. [65], the vast majority of construction companies in the USA are applying BIM tools in their projects. Figure 3 also indicates that BIM tools are widely used in terms of energy efficiency in urban planning projects in developed countries, with an insignificant application in developing countries. However, at present, China is the only developing country that uses BIM in urban planning projects, high application of BIM tools for energy assessment in commercial sector projects, and low application in residential projects, respectively. According to Smith [62], the latter could be related to the resistance of certain stakeholders towards the adoption of BIM, as most of them tend to prefer lower costs over the potential benefits of adopting BIM tools. It is evident that BIM tools are mostly used either in the case of working with a larger scale client or in projects that are done in collaboration with international companies. The thirteenth 5-year plan initiated in 2015 was aimed at implementing more sustainable construction practices by the end of 2020 [61]. Thus, these kinds of initiatives serve as a driving factor for higher levels of application of BIM technologies in the commercial sector and an initial step towards urban scale planning projects. Figure 3 also shows that there is a positive movement towards the application of BIM tools in retrofitting and medicine-related projects.

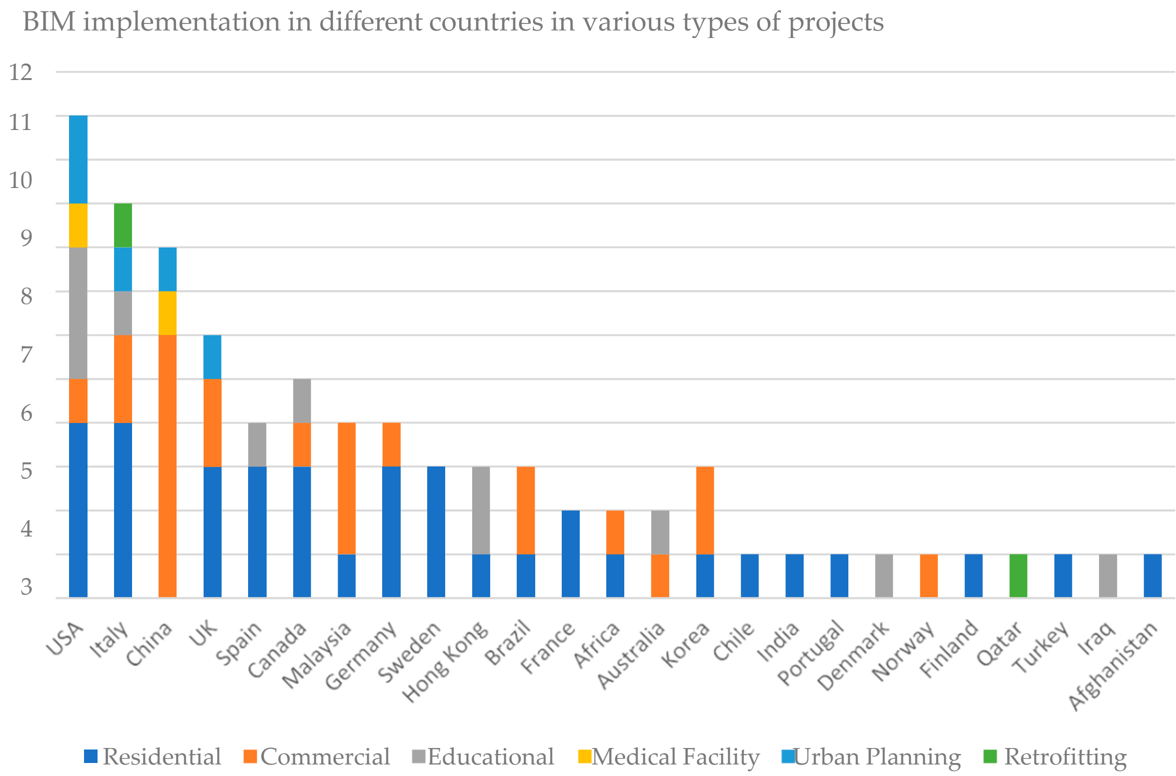

Figure 3. BIM implementation in different countries in various types of projects.

Although the energy-related criterion is highly sought after in sustainable construction practices used in existing buildings, there are still numerous barriers to adopting BIM tools as facility management tools in retrofitting projects [66,67]. Two primary reasons for lower BIM application in facility management areas are the interoperability issues and a lack of information required to enhance existing buildings' performance [67]. Furthermore, Figure 3 indicates that BIM is widely used in developed countries' residential and educational buildings in comparison to developing countries. In addition to standardisation, governments in developed countries tend to be focused on enhancing the overall performance of buildings by simultaneously protecting the environment and reducing the costs [68]. For instance, the UK's Government has set a goal of achieving approximately three-tenth of savings in terms of the whole life cycle cost of buildings by the end of 2025. In turn, in developed countries, more importance is given to improving the standard of living in residential buildings and enhancing the indoor conditions in educational buildings, and thus providing visual and thermal comfort, which in turn improves the quality of the campus experience for students [69]. There are a number of barriers to the implementation of BIM technologies in developing countries, such as, a lack of standardisation, low awareness and expertise levels, as well as high costs of investment and a lack of collaboration among stakeholders [70].

4.3. Types of BIM Tools and Their Utilisation in Different Forms of Projects

Figure 4 presents the number of articles that report on BIM energy assessment tools used in different project types, such as residential, commercial, urban planning, and educational buildings. Architectural BIM tools are used to create digital models for the purpose of designing structural, mechanical, electrical, and other systems of the buildings' purposes and also helps to identify issues or detect clashes [41]. As can be seen in Figure 4, Revit is the commonly used architectural tool, according to the reviewed journal articles considered in this study. When it comes to energy assessment, Green Building Studio is the most used tool. There is a common trend across all studies, as most of the studies have shown that combining Revit with Green Building Studio is a successful way to analyse energy assessment in buildings.

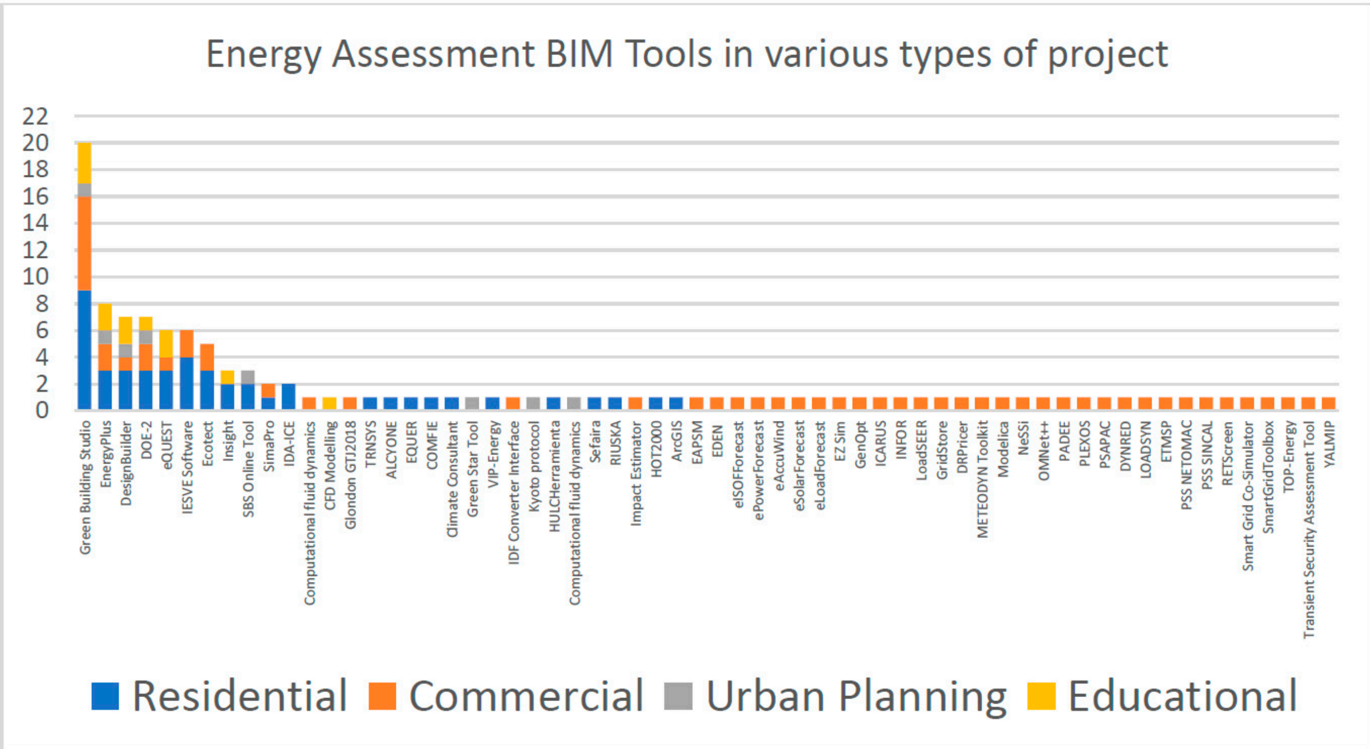

Figure 4. Energy Assessment BIM Tools in various types of projects.

Revit sets a comprehensive and flexible database tool for a range of project types. Energy Assessment software has been designed specifically to import architectural models, addressing the implications of tool suitability [41]. Stakeholders, in this case, tend to be familiar of tools' combinations through each early design and construction phase. ArchiCad was found to be another very commonly used architectural tool following Revit.

e-Quest and DOE-2 are simulation engines that are used to extract results from Green Building Studio [19], which has given these tools higher quality results. DesignBuilder is another comprehensive and widely used tool, which uses EnergyPlus as a simulation engine to perform the energy performance simulations [19]. In Spain, the DOE-2 calculation engine is used along with ArchiCAD or Revit tools to enable the exchange of information [49].

It is reported that the main consumers of energy are generally residential buildings [8]. Residential buildings are, therefore, responsible for a great share of CO_2 emissions. Many studies have attempted to improve their energy consumption. As discussed by these articles, application of BIM tools during the early design phases creates opportunities for assessing all variables [41]. An individual assessment of requirements for energy targets refers to these results, as different priorities would be set. A good example of this could be the computational fluid dynamic (CFD) tools selected for geometric wind flow simulations, specialising in energy performance using location-based weather data files and calculation engines [19].

Urban planning and educational project types are government-based projects. There is a pattern shown in Figure 4 demonstrating that these project types have not been reviewed as much as commercial and residential. Government funds provide a better opportunity to employ best practices to provide an optimal cost for achieving desired energy efficiency. Revit can produce the material quantities of an embodied emission calculation. A combination of BIM with LCA has the potential to control the life cycle impact by decreasing the workload for operational purposes. It provides an environment for a realistic assembly of building information.

4.4. Promoting Buildings' Energy Efficiency Using Hybrid BIM Tools

From the phase of separating the performance categories, to early design and advance design, to the construction phase, there is a need for a timetable and grid for additional tools. Planning this layout will mean stakeholders (e.g., designers) will have better control over the coherency of the selected design software and plugins [49]. For example, Galiano-Garrigós et al. [49] used multiple tools, such as Revit, Climate consultant, Arquimedes Cype, Green Building Studio, e-Quest, IES VE, Sefaira, and HULC (herramienta unificada LIDER-CALENER), which were available from Spain's software resources. In the early design phase, they used a main architectural modelling tool (Revit) to produce the preliminary structure. It was followed by an EnergyPlus analysis program (Green Building Studio) to further identify parameters. DOE-2 EnergyPlus calculations were formed, allowing the integrated environmental solutions (IES VE) to be used. This continued to the advanced design phases, with improvements to the EnergyPlus analysis program (Green Building Studio); then, HULC runs the calculation engine and plug-ins to involve the information transfer. Then, DesignBuilder could be used to evaluate the energy performance of the building. Next, for the construction phase, in keeping with the same architectural modelling tool (Revit), the Arquimedes Cype could be employed to examine each material and their CO_2 emissions and Inventory of Carbon Energy (ICE) [49].

4.5. BIM Integrated Life Cycle Assessment (LCA)

Nearly a half of the total amount of annual greenhouse gases are generated by the construction sector, which also consumes four-tenth of raw materials used in the world [33]. Therefore, to enhance the efficiency of buildings in terms of energy usage, a great emphasis must be given to the evaluation of building materials' consumption and their impacts on energy use and on the environment during the early design stages [71]. Initially, the life cycle assessment of buildings is taken into consideration when construction is nearly at the handover stage. There is no involvement of LCA in design stages, which hinders overall building performance evaluation, as a number of factors, such as building materials, their composition, and their interaction with other building elements, are not taken into consideration and results in obtaining contradicting results [71]. In addition, LCA does not cover the operational phase of a building; it includes various procedures, policies, and frameworks adopted right from the early design stage until the end of the building's life. The integration of BIM with LCA is one of the best measures to improve energy efficiency throughout the life cycle of buildings [33]. BIM provides time and cost reductions throughout a project's life cycle, from the early design phase to a building's operational stage [42].

To achieve net zero energy standard buildings, it is critical for projects to enhance energy assessment. The integration of LCA with BIM at the early design stage is an interactive and dynamic approach that serves as a single platform, where several policies, frameworks, and procedures are integrated and aimed at achieving results in a collaborative manner rather than separate works [71]. For instance, the life cycle inventory stage in the work of [33] collects and assimilates various building material data into building design in order to evaluate the building's overall energy performances. This further aids in assessing various alternatives, and their energy demand can be evaluated before the commencement of construction, which helps to properly select the materials that will enhance energy efficiency of the building [33]. Najjar et al. [71] evaluated and compared two alternatives: (1) building with only aluminium curtain panels and the masonry brick wall-type with mortar and paint, and (2) building with aluminium and glass panels and the masonry brick wall-type, ceramics, and mortar. In terms of energy usage, building type 1 consumed 660,472 kwh/year, while building type 2 consumed 612,281 kwh/year. Moreover, lighting and HVAC demands were approximately 4% more for building type 1. However, in terms of the whole life cycle, as building materials were correlated with other parameters, such as climate conditions, building location, and several other parameters, building type 1 results were better than those of type 2. Additionally, building type 1 emitted just 3% of harmful gas emissions throughout its life cycle, while type 2 recorded 9% [71]. Therefore, the BIM-LCA approach at the early design stage does not only enhance the buildings energy efficiency, but also contributes to mitigating the detrimental environmental impacts by considering passive negative effects originating from building materials, e.g., ozone depletion, global warming, and acidification, throughout the overall life span of buildings [71].

4.6. BIM in Assessing Building Components

To construct a building of a higher energy efficiency level, it is essential to control energy consumed by a building throughout the year. Every building consumes energy both actively and passively [23]. Energy consumed by various systems and services in a building, such as heating, ventilating, and air-conditioning (HVAC), and lightning are examples of the active consumption of energy [23]. On the other hand, several factors such as location, orientation of building, building materials, and weather conditions contribute passively to the total energy consumed by a building. Key elements that are responsible for passive energy consumption are building façade, walls, windows, and roofs. According to Kim et al. [47], nearly one-tenth of a building's energy loads depends on the window design parameters of the building. In this regard, the most important parameters of window design are the window's size, position, and orientation in the building. Kimet al. [47] and Kaasalainen et al. [72] rejected the concept of larger-sized windows to achieve better views. Moreover, both studies concluded that the larger size of windows results in higher energy demand and fluctuations in energy loads.

Further, Kim et al. [47] performed a total of 65 simulations, out of which 29 were performed to identify the best size windows for buildings, and the rest of the simulations were performed to determine the most suitable position and orientation of window for the best-sized windows, as evaluated through the prior 29 scenarios. A building tends to have better energy efficiency results when its windows are facing north and east directions are positioned at nearly centre. Additionally, Kaasalainen et al. [72], in their study, stated that the north orientation is the most preferred orientation of windows to achieve higher energy efficiency results. Both Kim et al. [47] and Kaasalainen et al. [72] concluded that higher energy efficiency in buildings can be obtained by utilising BIM to evaluate energy consumed by the building services, in relation to additional factors described above. However, there are several uncertainties that still prevail in current BIM practice, which hinder the most beneficial solution possible for any building. Some of these uncertainties are due to neglecting the external shades, textures of building, building materials, variation in sun angles throughout the year, not evaluating any scenario in terms of various locations and climatic conditions, and elimination of lighting loads. Some of these uncertainties, such as external shading, various climatic conditions, and locations, were considered and evaluated by Kaasalainen et al. [72], through which the authors achieved the enhancement of building energy efficiency. However, both studies by Kim et al. [47] and Kaasalainen et al. [72] strongly suggested an integrated, collaborative approach with the use of BIM for optimum energy efficiency in buildings. A similar work was conducted by Theresa Innocent and Ramalingam [23] on reducing energy consumption in buildings by selecting the most preferred materials for a building façade. They stated in their work that not only the material of the façade (which contributes to achieving energy conservation), but also the performance of the façade materials in terms of its interaction with changing climatic conditions, geographic locations, and other significant factors must be well taken into account. They conducted their research on residential buildings and two materials, namely, brick and exfoliated vermiculate (EV), which were compared in the integrated BIM platform. The assessment results showed that the EV provided better thermal, visual, and indoor comfort, along with a reduction in annual energy consumption. Therefore, Theresa Innocent and Ramalingam [23] stated that BIM can help to mitigate a high energy requirement to a greater level by simulating building design, along with climatic, environmental, and other energy parameters. A building's dynamic simulation, which assesses the energy consumed by a building's systems and services, along with the interaction of the building façade with the environment, yielded more precise energy consumption details than the simulation that considered solely the assessment of energy consumption by building services.

5. Conclusions

The main notion behind the current study is that the use of BIM has a paramount effect on the energy efficiency assessment of buildings. The systematic literature review of the studies (77 articles) on the subject showed that developed countries compared to developing countries are more interested in using BIM within their construction projects. This proves that developed countries are more aware about the positive effects of BIM tools on main projects' objectives, such as reducing the cost and duration of the overall project while keeping the construction quality. Perhaps this could also be attributed to the willingness to adopt BIM, while some countries mandate (e.g., UK) its adoption. While the residential projects are where various BIM tools were used, the USA and China, two leading countries in the use of new technology, have used BIM more in residential and commercial projects, respectively. These data give insight to decision makers, who are active in China's construction industry, to encourage construction companies in residential sectors to use BIM to approach several benefits of applying such technologies, such as using less material, shortening construction time, improving energy efficiency, etc. The most popular and efficient BIM tools in energy assessment have been uncovered. This outcome can help architectures, engineers, and construction companies, which boosts the process of decision making in selecting the most reliable BIM tools for energy assessment and architectural purposes. A high variety of BIM tools have been used for energy assessment in the commercial sector; meanwhile, Green Building Studio has been the most popular and powerful BIM software for energy assessment in all sectors. This study, through a literature review, proves how integrating BIM with other tools and evaluating the life cycle assessment can promote energy efficiency in buildings.

In some areas, BIM is not used to the most of its potential, as stakeholders need to use the appropriate methodology along with LCA. In energy assessment, BIM can be evaluated through the building's geometry, weather conditions, materials related to inputs and outputs, and other energy performance-affecting factors. BIM tools are capable of creating a comprehensive supply of information at the early phases of a building project to compare performance and evaluate limitations before the operational phase.

BIM can improve decision making processes for stakeholders and help them deliver energy-efficient buildings. Hybrid approaches can be developed for targeting energy savings in the advanced stages by selecting appropriate tools and plugins to support the transition of information with minimal data loss. This approach delivers informative results, which are closer to real-life situations. As most of the programs can share calculation engines, the databases deliver a range of results. It takes an in-depth understanding to determine what data are needed to provide accurate results, considering all aspects of parameters crossed with energy supply.

Tool selection can suffer from problems between the method and the program used. This can influence the results produced. As the adoption of inefficient design decision making at early phases can decrease the utilisation of BIM tools, LCA needs to be integrated to examine the whole life cycle of the project instead of using the traditional approaches. The results showed that the combination of BIM and LCA can lead to improved results in delivering energy-efficient buildings.

While it is believed that the present study can provide an insightful description of the existing literature on the BIM use in energy assessment of construction projects, the research outcomes should still be treated with caution. Therefore, future studies are recommended to carry out research on the accuracy of the BIM-based predictive energy model with the actual energy performance for various types of construction projects. Secondly, the effect of BIM use in energy efficiency and its impact on the Industry 4.0 concept could also be another research for the future. Thirdly, future studies are recommended to perform a network analysis for bibliometric mapping of BIM utilisation in energy assessment.

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