



Impact of Applying Sustainable Building Design Criteria on Building Environmental Performance: Using Building Information Modeling for Assessment

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Abstract. Presently, the Architecture, Engineering, and Construction sectors have been significantly affected by sustainability concerns. Sustainable construction is regarded as one of the critical and essential decisions that aids in minimizing building environmental impacts and energy consumption. and as a consequence, enhancing overall building sustainability levels. this research attempts to account for contemporary considerations towards sustainability and higher environmental performance of buildings, and aims to investigate the impact of applying smart glass in building envelop on building environmental performance, explore the capabilities of BIM in building sustainability and environmental performance assessments, and develop an integrated framework for sustainable building design with enhanced environmental performance. For this purpose, a building with large glazing area envelop in Erbil as case study. Building modeling is generated using Autodesk Revit and sustainability assessments are performed using Insight for Revit. Results indicate that smart glass consideration for building envelopes greatly influences the building design in terms of building energy consumption and overall building environmental performance.

Keywords: Sustainable Building Design, Environmental Performance, Smart Glass, Energy Consumption, BIM

أثر تطبيق معايير تصميم البناء المستدام على البناء

الأداء البيئي: استخدام نمذجة معلومات البناء للتقييم

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ملخص

وفي الوقت الحاضر، تأثرت قطاعات الهندسة المعمارية والهندسة والبناء بشكل كبير بمخاوف الاستدامة. يعتبر البناء المستدام أحد القرارات الحاسمة والأساسية التي تساعد في تقليل الآثار البيئية للبناء واستهلاك الطاقة. ونتيجة لذلك، تعزيز مستويات الاستدامة الشاملة للمبنى. يحاول هذا البحث مراعاة الاعتبارات المعاصرة نحو الاستدامة

والأداء البيئي العالي للمباني، ويهدف إلى دراسة تأثير تطبيق الزجاج الذكي في غلاف البناء على الأداء البيئي للمبنى، واستكشاف قدرات BIM في تقييم استدامة البناء والأداء البيئي، وتطوير إطار متكامل لتصميم المباني المستدامة مع تعزيز الأداء البيئي. لهذا الغرض، تم تصميم مبنى ذو مساحة زجاجية كبيرة في أربيل كدراسة حالة. يتم إنشاء نماذج البناء باستخدام Autodesk Revit ويتم إجراء تقييمات الاستدامة باستخدام Insight for Revit. تشير النتائج إلى أن مراعاة الزجاج الذكي في أغلفة البناء يؤثر بشكل كبير على تصميم المبنى من حيث استهلاك المبنى للطاقة والأداء البيئي العام للمبنى.

الكلمات المفتاحية: تصميم المباني المستدامة، الأداء البيئي، الزجاج الذكي، استهلاك الطاقة، BIM

1. Introduction

Presently, development regarding sustainability comes to three major categories: 1- Social Sustainability, that is the impact of a system on the society, 2- Economic Sustainability, that is the economical association, and 3- Environmental Sustainability, that is the impact on the environment [21]. These three sustainability categories were first indicated by Elkington in 1994 [22] and continues to the present. The three categories of sustainability are illustrated in Figure (1.1). This study focuses on the environmental sustainability category as it considers impact of applying sustainability criteria on building environmental performance. This is to shed light on building impacts on the environment and how these impacts can be reduced considering sustainable building design criteria (Author).

Figure (1.1) Three Categories of Sustainability indicated by Elkington. Image Source: (Author)



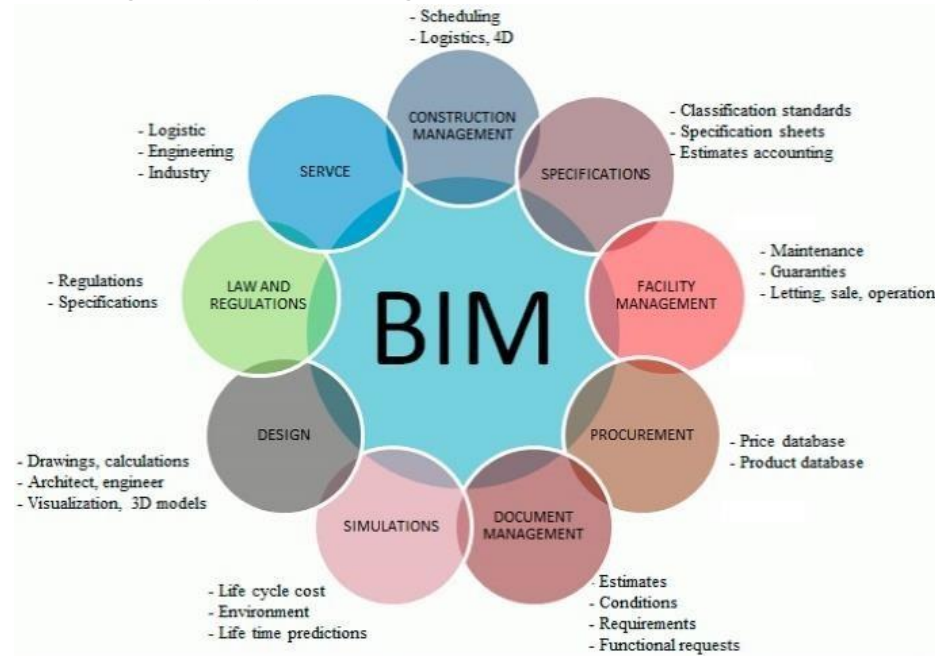
Finding out criteria for a sustainable building design is a new development. Sustainable development was internationally defined in 1987 in the publication of the report of the world commission on environment and development as “the development that not only meets the present needs of society but also does not compromise the needs of future generations”. This definition provides basis for determining certain sustainable building design criteria. Based on the sustainable development definition, certain components can be considered by architects and designers to conduct building sustainability assessments. For instance, the building function and its capability of adapting to forthcoming demands, and considering used building materials. Sustainable building design criteria commonly consist of factors like energy efficiency, use of smart building materials, water conservation, and waste reduction. It



focuses on reducing environmental impact and promoting long-term sustainability [23].

Nowadays, the Architecture, Engineering, and Construction (AEC) sectors have been significantly influenced by considerations regarding sustainability. Sustainable construction is broadly considered as one of the primary decisions to minimize building environmental impacts [24]. It is essential to consider certain sustainability criteria in order to perform assessments regarding environmental performance of buildings and manage sustainable building design and construction. For this purpose, considering certain building rating systems is crucial. Nowadays, one of the most prominent rating systems for sustainable buildings worldwide is LEED (Leadership in Energy and Environmental Design), that is developed by the United States Green Building Council (USGBC) for assessing building environmental performance and impacts of buildings on the natural environment [25]. In study [24], it is indicated that numerous scientific efforts have been devoted to promoting sustainability through adopting different techniques. One advanced technique that has been applied to achieve building sustainability and optimized building environmental performance assessment process is Building Information Modeling (BIM) technology. According to an explanation about BIM provided [26], 3D modeling idea, building information, and data primarily form the advanced virtual building model that make way for professionals working in the AEC industry to design projects, carryout building simulation processes, and share all organized and stored data within the model easily among project team members. The building model includes all necessary details regarding the building, building geometry and spatial relationships, and building components and characteristics that are essential for all project team members during all stages of a building project lifecycle. Recently, majority of the recognized and accepted BIM based tools and software incorporate built-in features and capabilities required for building environmental performance assessment, that can be performed throughout simulation process. In this regard, all associated project members will be capable of initiating and setting out building sustainability and environmental performance assessment during early phases of the project. With considering BIM, improvements in building sustainability and environmental performance can be observed [6]. BIM considers different dimensions, including 3D: providing detailed three dimensional model of building, 4D: considering time and providing schedule to project delivery, 5D: providing cost estimation for the project, 6D: performing building sustainability, environmental performance, and energy consumption assessments through simulation, 7D: providing facility management and tracking building status, and 8D: considering occupant's health and security through identifying risks [27]. Figure (1.2) indicates the stages of BIM use and the tasks it can perform in each stage.

Figure (1.2) BIM stages and tasks. Source: [27]



Presently, creating interchanging information between project team members is regarded as a complex task in the AEC industry. A well prepared BIM model consolidates all required data and information of a project. Furthermore, the BIM model prepares satisfactory documents for more preferable building construction, and collects information needed for building sustainability assessments. Using BIM aids in fulfilling the requirements necessary to achieve sustainable building design [28]. Previous studies demonstrate that building sector consumes large amount of energy. consequently, proper strategies to enhance building sustainability need to be considered. Authors in previous studies also indicated that applying BIM for building sustainability and environmental performance assessments considering certain criteria instead of traditional CAD based applications aids in more precise performance of building energy consumption and analysis.

Although an abundant number of recent studies have been conducted on the impact of applying sustainable building design criteria on building environmental performance, very few attempts have been made to address the impact of applying smart glass criterion with taking into consideration significant variables collectively, on enhancing building environmental performance. To bridge the gap in knowledge, this research provides a framework to integrate smart glass criterion into building design considering certain significant variables using BIM as an assessment tool. This is to enhance building environmental performance and sustainability.

Overall, this research attempts to account for contemporary considerations towards sustainability and higher environmental performance of buildings, and aims to investigate the impact of applying smart glass in building envelop on building



environmental performance, explore the capabilities of BIM in building sustainability and environmental performance assessments, and develop an integrated framework for sustainable building design with enhanced environmental performance based on applied criteria and assessments results obtained.

2. Literature Review

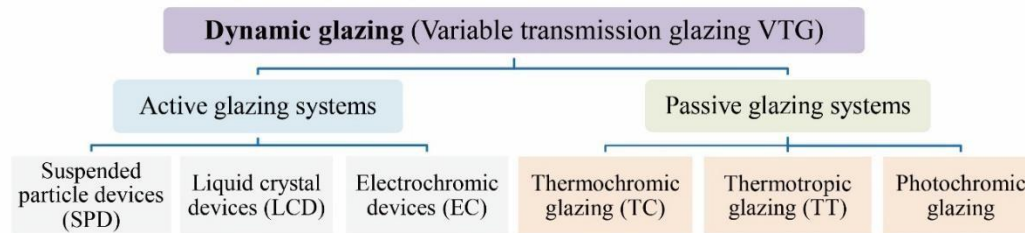
2.1 Sustainable Building Design

Many theories have been proposed to demonstrate the significance of sustainable building design and what influences building environmental performance. In study [1], it is indicated that a sustainable building is regarded as an environmentally friendly building that can positively influence the environment during its lifecycle. It is crucial to select appropriate building parameters, including: building materials, building envelope, structure of building interior, and window to wall ratio in order to obtain a sustainable building because these parameters significantly impact building energy use. In study [2], it is indicated that sustainable buildings can reduce the negative impacts of buildings on the natural environment, as they consider efficient use of energy, sustainable and environmental friendly building materials, and indoor environmental quality. Based on study [3] conducted, sustainable development looks into the rational use of natural resources, associating the environment with technology. The building sector is at the forefront that must obtain sustainable development, that is a major incentive of building energy efficiency and the sustainable building movement. Sustainable buildings, from social, economic and environmental sustainability and building lifecycle point of view, aim to reduce building energy and water consumption. for instance, appropriate selection of building components (wall, window, ceiling, roof, and floor) can significantly enhance building energy efficiency. Furthermore, sustainable building maximizes resource saving through entire building lifecycle, in addition to protecting the environment, reducing environmental pollution, and providing energy efficient spaces for people. In study [3], it is indicated that the construction sector in Iraq is regarded as the sector with the most energy consumption and the greatest impact on the environment. This is due to lack of building energy performance assessment in the early building design stages, and inconsideration of building energy performance assessment by architects. Study [3] discussions are regarding assessment of building energy efficiency that clearly indicate the significance of incorporating sustainable building design criteria into building design. The aim of applying these criteria is to reduce building energy use, this is through focusing on certain aspects, including building envelop optimization through using smart and sustainable materials, energy efficient strategies, and lighting and high performance HVAC systems. Considering these strategies aid in minimizing building energy consumption. in study [4] it is indicated that considering building materials and insulation layers are an essential in sustainable building design. Windows and walls are regarded as important parts of sustainable buildings. Windows have significant impact on building energy consumption and are used mainly for daylighting, ventilation and thermal insulation. Based on study [5], building sustainability is significantly affected by the environmental impact of building materials. Buildings



have negative impact on the environment not only in the construction phase, but also in the operation phase. Sustainability progress is associated with awareness of social, economic, and environmental dimensions. Based on study [8], building quality is an important aspect in the construction field. In order to obtain buildings with high architectural quality, it is crucial to consider building sustainability assessment tools. In the construction sector, a continuous drive towards sustainability and sustainable building design is observed. Sustainability, according to the American Institute of Architects (AIA), is “the ability of society to continue surviving in the future without being forced into decline due to the depletion of the natural resources on which it depends”. Based on study [11], the construction sector has become more interested in the design and construction of eco-friendly buildings, providing high performance and cost savings. Buildings require substantial amount of energy and have negative influences on the environment. Consequently, sustainable buildings have been suggested in order to minimize building environmental impacts and save energy, as they are eco-friendly with energy efficient formation. Another study [12] indicate that sustainable building design development has obtained considerable significance in architecture field. The aim of AEC industry is to construct high performance and sustainable buildings. Currently, with the rising concerns regarding immoderate consumption of energy and pollution, it is essential to follow green building practices. According to previous studies of [12], green building is a sustainable building that applies renewable building materials and energy saving techniques. In order to investigate building energy consumption, study [13] examined certain design factors, including building orientation and glazing type and size. The primary objectives of sustainable buildings are to reduce the negative impacts of building construction on the environment. In study [14], it is stated that traditional design of building gives static and uniform design alternatives for the building envelop. The use of smart glass in building envelop can produce optimum solutions to adapt buildings to different environmental conditions. Therefore, enhancing occupants thermal comfort and contributing to obtaining sustainable development goals, and consequently, improve health, tackle climate change and responsible energy consumption. building envelopes, mainly highly glazed, need to be smartly designed in order to interact with the surrounding environment, to provide high performance envelopes compared to conventional envelop performance. In study [14], smart envelop is defined as advanced performance for the building envelop with smart design related to climate conditions and technological solutions for construction. For instance, smart windows, smart insulation, smart façade and smart systems and smart technological equipment solutions as smart management systems, all to provide excellent indoor environment for occupants regarding thermal comfort, indoor environmental quality, and efficient energy conservation. Regarding the low-e glass discussed in study [14], low emissivity coatings are spectrally selective thin films applied to a multiple glazing unit that let the visible light pass through and block the IR and UV wavelengths, that generally create heat to reduce radiant heat emission and provide thermal insulation. Study results demonstrated that low-e glass provided thermal and solar control while allowing higher levels of natural daylight or visible light transmission. Figure (2.1) indicates the classification of smart glazing.

Figure (2.1) Classification of Smart Glazing. Source: [14]



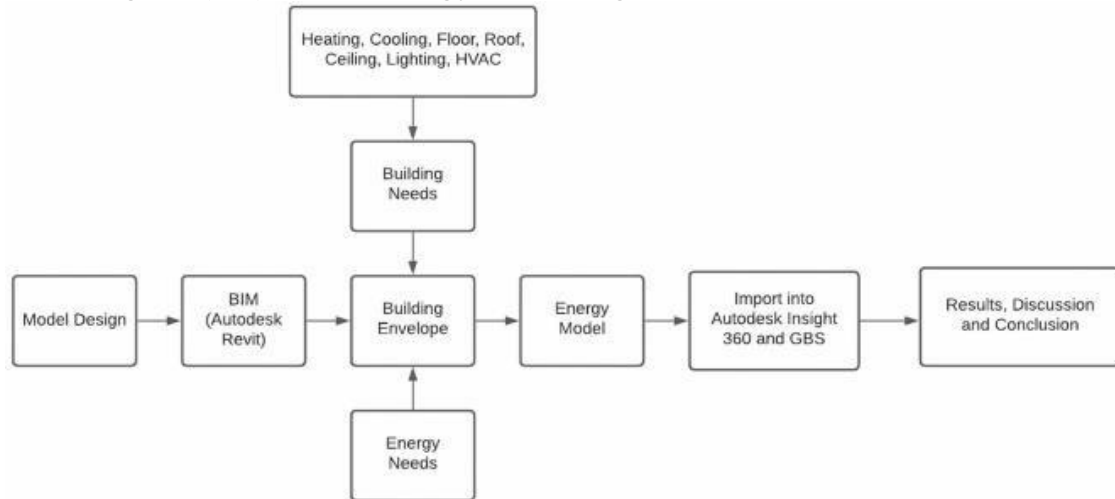
Simulations carried out in study [14] proved the effectiveness of retrofitting the existing glass with smart glass in enhancing the building thermal performance. Authors indicated that the use of smart glass in building envelopes significantly influence cooling loads, building thermal performance and energy consumption. in study [15], it is indicated that using smart glass, that aids in controlling the amount of light and heat accessing a building, is regarded as one of the possible methods to minimize building energy consumption and maintain proper level of comfort for occupants. Smart glass significantly influences the performance of building envelop. Utilizing advanced smart glazing results in reducing the usage of mechanical air conditioning systems, with significant advantages in term of energy saving. Furthermore, smart glazing systems allow influential regulation of daylight levels for visual comfort management [16].

2.2 BIM for Building Sustainability Assessment

Based on study [1], improvements in BIM and building energy performance simulation have provided opportunities for building energy optimization, as energy consumption in the AEC industry constitutes large loads in terms of pollution and global energy. Although estimating building energy use is crucial, precise estimation of energy use in early building design phase remains a complex subject. Building energy consumption simulation is often associated with BIM. Through BIM based energy simulation, the building performance is optimized. Since BIM model includes large amount of building data and information, its energy consumption model has a significant role in developing building energy sustainability. Decisions that are made regarding sustainable building design can be supported by applying BIM tools to improve building energy performance. BIM tools can also monitor and estimate energy consumption of existing buildings. The building envelope, which is considered as a design parameter affecting building performance, is a barrier separating building interior from exterior. The building envelope is an important factor in controlling and determining indoor environment quality. Buildings contain large amount of information that needs to be contemplated. Consequently, evaluating energy impacts of building parameters is not an easy task. Therefore, BIM is considered a significant tool to simulate the building performance assessment processes. BIM can assist designers in selection of building materials with appropriate energy performance in early stages of design because it can provide different design alternatives. In study [1],

used BIM tools include Autodesk Revit, Insight and Green Building Studio to perform building energy data analysis processes. Figure (2.2) demonstrates the method applied in study [1] regarding Revit energy modeling workflow.

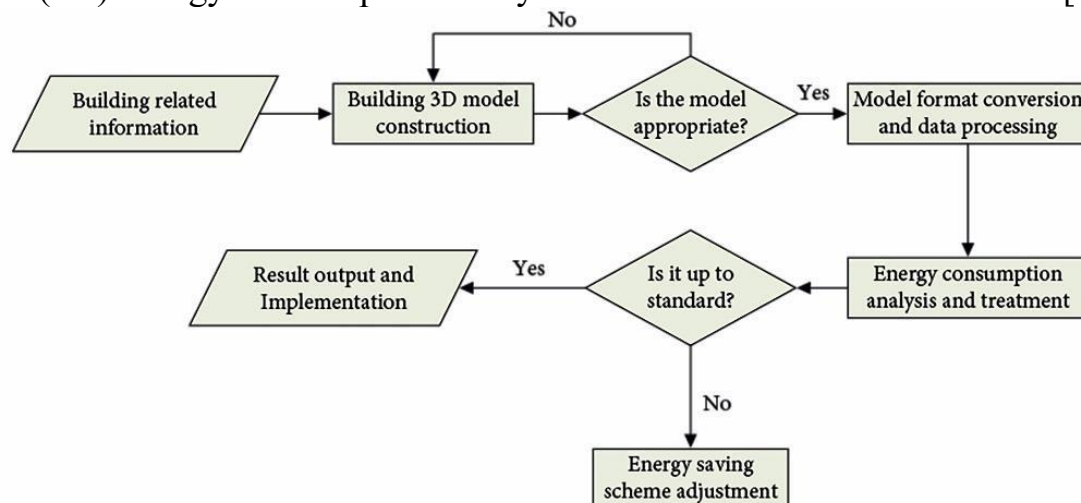
Figure (2.2) Revit Energy Modeling Workflow. Source: [1]



Models generated with BIM can document building energy consumption during its construction and assess building energy and environmental performance during post-construction building stage. In study [2], argument is about BIM capabilities and its functional aspects in sustainable building design and construction, as BIM enables more accurate building modeling and analysis of different aspects as energy performance, material efficiency, and overall building environmental assessments. BIM is regarded as an inventive approach that can create virtual building models during early design stages, assess building energy performance through simulation, manage building construction process, and making buildings more sustainable. BIM can reduce unreliability in the energy model of buildings, this is through importing and analyzing building heat data and geometry. A BIM model includes information regarding building materials and thermal performance. Utilizing BIM for building environmental performance assessments considering certain criteria instead of CAD based applications aids in more accurate performance of building energy consumption and analysis [3]. In study [4], it is indicated that utilizing BIM in building design and construction enhances working efficiency, predicts inadequacy in design, and avoids extra building energy consumption. A BIM model can overcome the deficiencies of traditional building model, as it can visualize real scene of a building from various dimensions, and simulate different situations that may occur in the building process, this is because of several information contained in the BIM model. BIM model integrates building information, environmental and other necessary factors to simulate building energy consumption and assess the overall building environmental performance through using appropriate software. Figure (2.3) indicates the energy consumption analysis method based on BIM technology.



Figure (2.3) Energy Consumption Analysis Method based on BIM. Source: [4]



BIM, according to the American Institute of Architects (AIA), is defined as “A model based technology coupled with a project information database, which is accessible and shareable to various project participants”. BIM has significant role in integration of environmental sustainability with building projects. A BIM model provides accurate and detailed information for buildings, enabling architects and designers to select the best design alternatives to obtain sustainable building designs with high environmental performance. In study [6], it is indicated that part of required parameters for building sustainability assessment can be collected from Autodesk Revit: which is regarded as one of the most popular BIM based tool. Revit contains applicable parameters related to sustainable building design that can be operated during early building design stages. BIM capabilities significantly influences building sustainability and environmental performance. There are various BIM based software used to assess building sustainability levels. In study [9], it is indicated that most used BIM based software programs are Autodesk Revit, Green Building Studio, Ecotect and IES-VE. These BIM based programs are regarded as building sustainability assessment tools that assist in building sustainability optimization through integration with certain green building rating systems. In study [11], it is stated that architects and designers create 3D model of buildings using BIM based tools to visualize the project during early design stage, which is the most important stage for making decisions about building sustainability and environmental performance. Authors also indicated that Revit is among commercially available BIM tools that provides building performance visualizations, enabling calculations of the whole building energy consumption through certain stored parameters. The building construction industry uses BIM technology to support the analysis process of sustainable building design. Through integration of sustainable building design and BIM technology, architects and designers will be able to design sustainable buildings with high environmental performance, this is through making knowledgeable decisions in early building design stages. In study [13], it is indicated that using BIM is regarded as an essential method to obtain building sustainability. BIM is capable of facilitating and providing 3D visualization of the project.



Furthermore, BIM can be used as a tool to support sustainable decision making process, as it can minimize waste material, energy consumption of buildings and construction. BIM can be utilized to reduce building energy consumption through predicting the building energy required for lighting, equipment loads, heating and cooling. The integration of sustainable design approach and advanced technology into the building design reduce building energy consumption, environmental impacts, and operation and maintenance costs. Study [16] investigated building thermal performance through computational tools, this is to assess the effect of smart glazing in enhancing building energy performance.

Based on the literature review conducted, it is concluded that buildings can have great negative impacts on the natural environment. Building environmental performance has been linked to the application of sustainable building design criteria through various theories, all of which aid to provide the buildings with higher environmental performance and sustainability. BIM is a model based technology integrated with a project information database that is accessible and shareable to various project participants. Overall, through BIM simulations together with building data analysis, a positive impact on the optimal building energy consumption can be achieved (Author).

2.3 Research Questions

Obtaining a sustainable building design is a complex process, it requires knowledge, proper assessment tools, and advanced building technology in order to be performed. From this point of view, the subsequent research questions are raised:

- What is the impact of incorporating sustainable building design criteria on building environmental performance?
- How applying these criteria can ease the reduction of negative impacts of buildings on the environment?
- How considering a rating system can provide the requirements to obtain sustainability measures for assessment of building environmental performance?

3. Research Methodology

3.1 Research Method

This research follows a mixed method approach of both qualitative and quantitative. Utilizing qualitative research method enables exploring the research topic in depth. On the contrary, quantitative research method provides numerical data and statistical analysis for the research study. Integrating both research methods contribute to a more comprehensive understanding of the study.

3.2 Data Collection Method

For research data collection, it is crucial to consider certain criteria when selecting a building for the research case study. Certain criteria to select buildings for current research case study include: Building Size, Type, Location, Attainability of Building Data, Building Architectural Design, Type of Building Occupancy, and Building Energy Consumption. Another important criterion to be considered when selecting a building for current research case study is: The Building Exterior Glass Surface Area, as the main sustainability criteria applied to enhance the building environmental performance in this study is the application of smart glass. It is important to select buildings with large external glass surfaces, as they lack natural ventilation. Consequently, the buildings impact the occupants thermal comfort and indoor air quality. A building in Erbil City is selected for case study, the Wavey Avenue Towers which is a multi-storey building with large glazing area covering its envelop. Figure (3.1) shows the building selected as the case study.

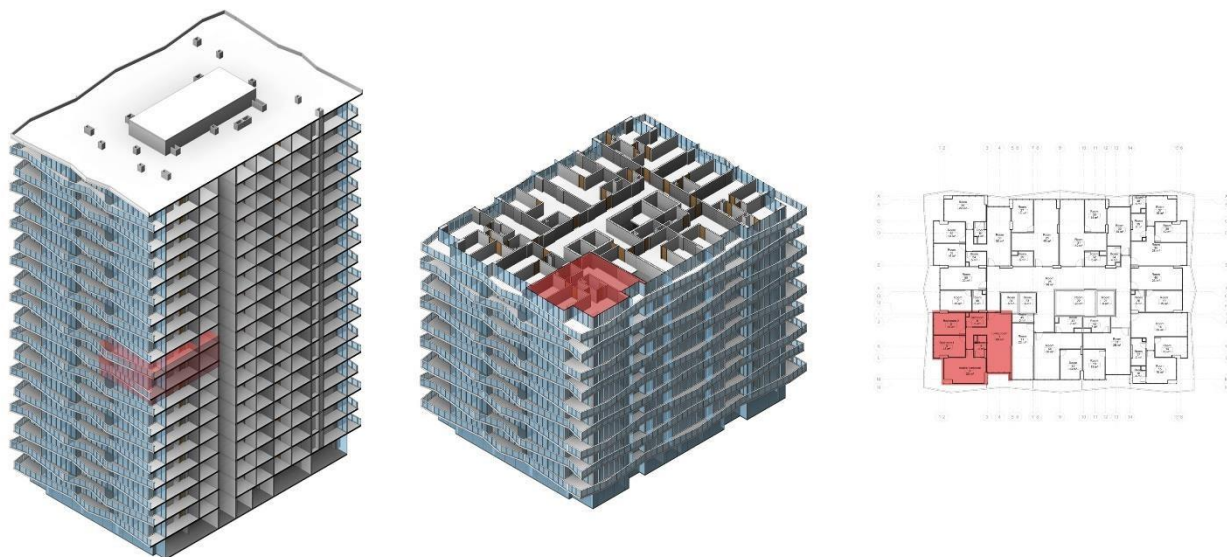
Figure (3.1) Wavey Avenue Towers. Source: [20]



3.3 Data Analysis

The building model for selected case study is generated using Autodesk Revit program, and certain assessments regarding building environmental performance and building energy consumption is performed using Autodesk Revit Insight, in which all are BIM based program and tools. BIM based programs aid in enhancing the building sustainability and environmental performance assessments processes that contribute to more sustainable building designs. This is through providing different design alternatives easy to modify in order to minimize overall building energy consumption and consequently, enhancing the building environmental performance. Results indicate the building energy consumption in (kWh / sqm / year) that can be used to determine annual cost for the energy consumed by the building. For the building energy consumption assessment, a single unit in level 9 in the whole building is considered. Figure (3.2) shows the whole tower building modeled in Autodesk Revit and the considered unit in level 9 for building energy consumption assessment is indicated in red color.

Figure (3.2) Building Model using Autodesk Revit. Source: ([Author](#))



4. Results and Discussion

4.1 Existing Building Condition

Regarding the building modeling, all architectural drawing details for the building are provided and imported in Autodesk Revit programs. With using Revit, the selected building with all its essential details are modeled, this is to assess the building existing condition in terms of energy consumption using Autodesk Revit insight for building environmental performance assessment. Afterwards, existing building unit glass is retrofitted with smart glass as well as testing different glazing properties considering certain significant variables within smart glass, this is to demonstrate the impact of smart glazing, the effects of significant variables within smart glass criteria, make comparison between the considered variables and overall, to enhance building environmental performance and sustainability, and therefore reducing building energy consumption.

4.2 Variables within Smart Glass Criteria

In the study, certain significant variables are considered, these factors are changed multiple times, this is to create various glazing type alternatives for the building envelop, and to indicate the variables with the greatest impact on the overall building energy consumption and environmental performance. Table (3.1) indicates the variables that are considered in the study and that are changed with each glazing alternative.

Table (3.1) Considered Variables within Smart Glass Criterion in this study. Source: ([Author](#))

No.	Considered Variable within Smart Glass Criterion
1	Thickness of Glass
2	Type of Glass
3	U Value



4	Thermal Resistance
5	Solar heat coefficient
6	Visual Light Transmittance
7	Vertical aluminum frame grid
8	Thermal Conductivity

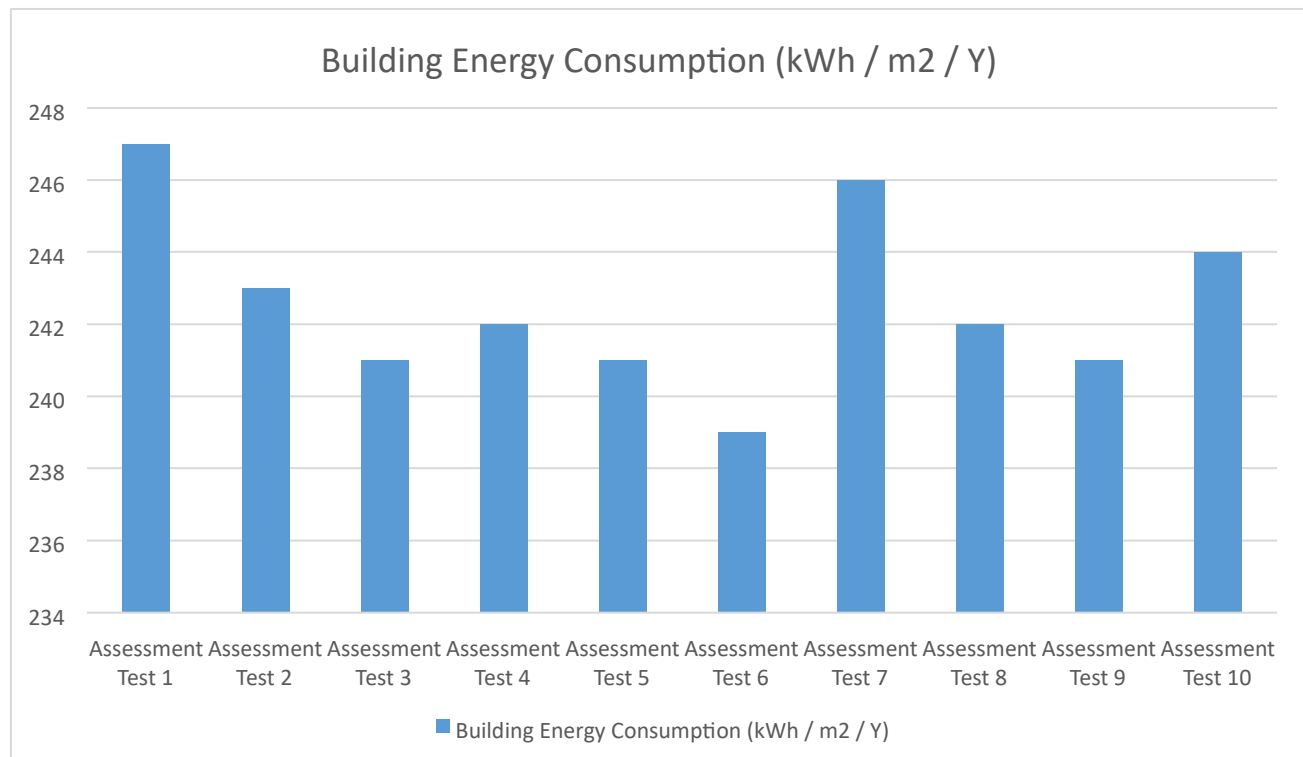
In this paper, multiple different building envelopes glazing design alternative are illustrated. In each design alternative, environmental performance assessment is performed using Insight in Revit program, this is to find out the most proper design alternative and to demonstrate the significance of each variable in reducing building energy consumption.

4.3 Assessment Results

As indicated previously, the considered variables are changed multiple times to observe their effects on building energy consumption. Results prepared in detail for all building unit envelop glazing alternatives are found in appendix. Overall, study assessments results indicate that the Low – e triple glazing with U-Value of (1.455 W/ (m². K), Thermal Resistance of glass (0.687 m². K / W), Solar Heat Coefficient of (0.26), and Visual Light Transmittance of (0.55) has the most efficient energy use among all other tested glazing alternatives and it has an annual energy consumption of (239 kWh / m² / Year).

Regarding the assessment results, its noticeable that the type of glass (Triple Glazing with Low – e Coating) has a greater impact on reducing building energy use and enhances its environmental performance as it has lower UValue compared to other glazing types. All alternatives that are assessed are generated with Revit Program and assessed using Insight for Revit. The chart below indicates the different glazing factors alternatives performed in this study and demonstrates the alternative with the most appropriate energy consumption.

Different glazing factors alternatives performed. Source: (Author)



5. Conclusion

5.1 Conclusion

This study aimed at determining the impact of applying sustainable building design criteria (smart glass criterion) on overall building environmental performance and energy consumption. For this purpose, multi-storey building in Erbil city is selected as case study. The building envelop consists of large glass area that is necessary to observe the effect of smart glass variables considered in the study. To perform the environmental assessments, Autodesk Revit program is used for building modeling, and Insight for carrying out environmental performance and energy consumption assessments of the building. In the assessment, multiple glazing design alternatives with differences in the variables are tested in order to observe the variables that affect building energy use and environmental performance the most, and to determine the most appropriate design alternative to enhance the building environmental performance. Results prepared in detail for all building unit envelop glazing alternatives are found in appendix. Overall, study assessments results indicate that the Low – e triple glazing with U-Value of (1.455 W/ (m². K), Thermal Resistance of glass (0.687 m². K / W), Solar Heat Coefficient of (0.26), and Visual Light Transmittance of (0.55) has the most efficient energy use among all other tested glazing alternatives and it has an annual energy consumption of (239 kWh / m² / Year).

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5.2 Recommendations

In order to apply the sustainability strategies for enhanced building energy use and environmental performance, policy makers need to consider certain sustainability criteria in building designs and sustainability assessments using advanced technologies as BIM to develop efficient building design regulations that can be applied in early building design stages. In addition, architects, designers, building owners, and educational team members need to consider more the significance of applying these sustainability criteria and how applying these criteria aid in more energy efficient buildings and enhanced building environmental performance.

References

- [1] Tahmasebinia F., Jiang R., Sepasgozar S., Wei J., Ding Y., Ma H. Using Regression Model to Develop Green Building Energy Simulation by BIM Tools. MDPI Sustainability Journal. 2022; 14,6262.
- [2] Cao Y., Kamaruzzaman S., N., Aziz N., M. Green Building Construction: A Systematic Review of BIM Utilization. MDPI Building Journal. 2022; 12,1205
- [3] Wang Ch., Cui B., Wu M., Tang Y., Boon J., Yap H., Zhang H., Li H. Building Information Modeling-Embedded Building Energy Efficiency Protocol for a Sustainable Built Environment and Society. MDPI Journal. 2022; 12,6051.
- [4] Zhao X., Gao Ch. Research on Energy-Saving Design Method of Green Building Based on BIM Technology. Hindawi Scientific Programming. 2022; 2108781.
- [5] Ahmad T., Thaheem M. J. LCIA Parameters and the Role of BIM towards Sustainability: Regional and Temporal Trends. MDPI Journal. 2022; 12,700.
- [6] Carvalho J. P., Braganca L., Mateus R. Sustainable Building Design: Analysing the Feasibility of BIM Platforms to Support Practical Building Sustainability Assessment. Elsevier. 2021; 0166-3615.
- [7] Veselka J., Nehasilova M., Dvorakova K., Ryklova P., Volf M., Ruzicka J., Lupisek A. Recommendations for Developing a BIM for the Purpose of LCA in Green Building Certifications. MDPI Journal. 2020; 12,6151.
- [8] Acampa G., Garcia J., O., Lopez C., D., Orasso M. Project Sustainability: Criteria to be Introduced in BIM. Valori e valutazioni Journal. 2020.
- [9] Chang Y., T., Hsieh Sh., H. A Review of Building Information Modeling Research for Green Building Design through Building Performance Analysis. Journal of Information Technology in Construction. 2020; 1874,4753.
- [10] Ansah M., K., Chen X., Yang H., Lu L., Lam P., T.I. A Review and Outlook for Integrated BIM Application in Green Building Assessment. Elsevier. 2019; 2210,6707.
- [11] Jalaei F., Jalaei F., Mohammadi S. An Integrated BIM-LEED Application to Automate Sustainable Design Assessment Framework at the Conceptual Stage of Building Projects. Elsevier. 2019; 101979.
- [12] Motamedi A., Han Y., Yabuki N., Fukuda T. Green Building Design Support System Based on BIM and LEED. ICCBEI and CCACHE. 2017; 317170398.



- [13] Watfa M., K., Hawash A., E., Jaafar K. Using Building Information & Energy Modelling for Energy Efficient Designs. ITCON Journal of Information Technology in Construction. 2021; 1874-4753.
- [14] Taher R., Abdelkader W., A., Fahim A., A., M., A Sustainable Building: To Achieve Thermal Comfort in Highly Glazed Buildings Using Smart Glass. IOP Conference Series. 2022; Volume 1113.
- [15] Brzezicki M. A Systematic Review of the Most Recent Concepts in Smart Windows Technologies with a Focus on Electrochromics. MDPI Journal. 2021; 13,9604.
- [16] Piccolo A., Marino C., Nucara A., Pietrafesa M., Energy Performance of an Electrochromic Switchable Glazing: Experimental and Computational Assessments. Elsevier. 2017; 0378-7788.
- [17] Autodesk Revit Program for case study building modeling.
- [18] Autodesk Revit Insight for Building Environmental Performance and Sustainability Assessments.
- [19] Site Visit to Existing Building Location selected as Case Study.
- [20] <https://lalav.com/projects-detail/Wavey-Avenue-Towers>
- [21] Bernardi E., Carlucci S., Cornaro C., Bohne R., A., An Analysis of the most adopted rating systems for assessing the environmental impact of buildings. MDPI Sustainability Journal. 2017; 9,1226.
- [22] Elkington J., Partnerships from cannibals with forks: the triple bottom line of 21st century business. Environmental Quality Management. 1998.
- [23] Whole Building Design Guide Sustainable Committee, 2021.
- [24] Xue K., Hossain U., Liu M., Ma M., Zhang Y., Hu M., Chen X., Cao G. BIM Integrated LCA for Promoting Circular Economy towards Sustainable Construction: An Analytical Review. MDPI Sustainability Journal. 2021; 13,1310.
- [25] www.usgbc.org
- [26] Kubba S., Handbook of Green Building Design and Construction, Chapter Five, BIM. Elsevier. 2017.
- [27] Reizgevicus M., Ustinovicus L., Cibulskiene D., Kutut V., Nazarko L. Promoting Sustainability through investment in Building Information Modeling (BIM) Technologies: A Design Company Perspective. MDPI Journal. 2018; 10,600.
- [28] Valdes F., Gentry R., Eastman C., Forrest S. Applying Systems Modeling Approaches to Building Construction. ISARC. 2016.
- [29]