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FULL LENGTH ARTICLE

The Impact of Building Material Modeling on Enhancing Building Sustainability (Shadow and Lighting): A Case Study of a Residential Building in Basilia

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ABSTRACT

This study examines the impact of building material modeling on enhancing building sustainability through a case study of a residential building in the city of Basilia. The focus is on using Revit 2023 to model the building and analyze how building materials affect its sustainability. The modeling process includes analyzing the shadows cast by architectural elements and studying their impact on the performance of the building materials. Shadow reflections on energy and material efficiency are measured to determine how building sustainability can be improved through material design and distribution adjustments. Additionally, Revit Insight 2025 is used to evaluate the extent to which natural lighting is achieved through the building envelope and to study the impact of materials on lighting quality and energy efficiency. The research addresses how the building benefits from natural lighting and how this can be optimized with appropriate materials to achieve maximum energy efficiency and reduce environmental impact. The study aims to provide a comprehensive model demonstrating how building sustainability can be enhanced through improved modeling of building materials and analysis of their environmental performance. Through these analyses, the research seeks to offer strategies and recommendations for designing more sustainable and energy-efficient buildings.

Keywords: Sustainable Buildings ▪ Green Buildings ▪ Environmental Assessment ▪ Assessment Systems ▪ Building Information Modeling (BIM) ▪ Building Envelopes ▪ Building Sustainability ▪ Shadow Analysis ▪ Sustainable Design ▪ Environmental Performance Assessment

1. INTRODUCTION

The growing focus on the aesthetic aspects of building envelopes often leads architects to neglect their energy efficiency. This results in a reliance on mechanical systems to provide thermal comfort, compensating for disruptions caused by arbitrary surface use in facades. This study addresses the environmental damage and the lack of knowledge about latent thermal energy storage in building envelopes. Additionally, it considers the impact of removing green spaces such as Razi Gardens for construction using unsustainable materials.

The objective of this study is to explore how Building Information Modeling (BIM) can enhance the sustainability of residential buildings. Using a residential building in Basilia as a case study, the research defines the principles and standards of green architecture design, assesses the impact of toxic emissions from building materials, and addresses the knowledge gap in thermal energy storage techniques. It evaluates how building envelopes can improve thermal performance and reduce energy loads and demonstrates how BIM technology can achieve sustainability.

The research highlights the need to redefine building practices to promote environmental sustainability and understand how construction can conserve the environment. It assesses the role of building envelopes in reducing cooling and heating loads and leverages BIM for sustainable construction. The study aims to reduce pollutant emissions from buildings, promote sustainable assessment tools, and present global examples of sustainable projects using BIM. This research proposes an improved model for building envelopes that manage climatic elements to achieve indoor comfort.

The study emphasizes the importance of sustainable construction practices and promotes a culture of sustainability in Syria. It aims to understand the role of building materials in thermal performance and mitigate the environmental impact of converting green spaces into construction zones [1].

2. LITERATURE REVIEW

2.1 Sustainability and Sustainable Architecture Standards

This section explores the evolution and principles of sustainability within the context of architecture and construction. Originating in the 1970s amid growing concerns over environmental degradation and developmental challenges, sustainability emerged as a pivotal concept. It gained prominence following the 1987 Brundtland Report, which defined sustainable development as meeting present needs without compromising future generations. Subsequent global conferences, such as Rio de Janeiro in 1992 and Johannesburg in 2002, underscored the urgency of integrating sustainability into global and local development agendas.

Sustainability, encompassing ecological, economic, and social dimensions, remains central to architecture and construction. Sustainable architecture, an integrated design approach, emphasizes resource efficiency and environmental responsibility across a building's lifecycle—from design and construction to operation and demolition. Key strategies include minimizing environmental impact, conserving energy and water, reducing waste, and promoting reuse and recycling [2]. Materials such as steel, glass, and prefabricated components are favored for their sustainability credentials, contributing to lower resource consumption and enhanced environmental stewardship.

Moreover, sustainable buildings not only mitigate environmental footprints but also offer economic benefits, including reduced operational costs and increased property values. They enhance indoor environmental quality, promoting occupant health and productivity while aligning with broader goals of sustainable development. Overall, sustainable practices should be integrated into future building endeavors to ensure long-term environmental and societal well-being.

2.2 BIM Technology and Its Role in Sustainability and Assessment

Building Information Modeling has emerged as a transformative methodology in the Architecture, Engineering, Construction, and Operations (AECO) industries, facilitating comprehensive information management throughout a building's lifecycle. Since its inception, BIM has gained fundamental recognition throughout these sectors. It encompasses coordinated and computable building data and facilitates design decision-making, building-performance prediction, cost estimation, and construction planning. BIM can be defined as a set of interactive policies, processes, and technologies that form a methodology for managing building-design principles and data in digital form throughout the building's lifecycle.

The advent of BIM has revolutionized traditional building-design processes by adding layers of data and enabling new methods of information exchange and communication among project stakeholders. Designers can modify building components in a unified model, allowing system-wide dissemination of changes across all project views. Applying BIM to real construction projects through a single model that serves as a single-source information repository presents several challenges; however, the methodology offers numerous benefits [3].

Visualization: BIM provides a better understanding of a building project and connects additional data dimensions to the model. **Change management:** Changes made in a BIM model are automatically reflected in all views, including floor plans, sections, and elevations. This facilitates collaboration on coordinated models and expedites documentation. **Building simulation:** BIM models include more than architectural data; they encompass structural models, Mechanical, Electrical, and Plumbing (MEP) systems, sustainability information, and other properties, allowing project teams to assess building performance before actual construction. **Data management:** A central purpose of BIM is to capture information and manage construction projects.

The transition to BIM methodology and the shift toward green-building concepts have enabled AECO stakeholders to integrate the emerging trend known as "Green Building Information Modeling" or "Green BIM" into sustainable building-design practices. The benefits of implementing BIM in sustainable design have been well documented in the literature and in industry practice. They include accurate information exchange, building-performance analysis, accurate cost estimation, and timely project completion.

BIM can be applied to sustainable-building development through a broad context of interactive policies, processes, modeling techniques, visualization, analysis, simulation, and documentation [4]. Green-building design is among the most extensively explored fields in BIM literature. Two principal types of software are used: BIM authoring solutions and BIM performance-analysis solutions. Authoring tools are often large applications used by design firms to generate and organize most of the model information. Revit, ArchiCAD, and Bentley, for example, provide additional functions such as presentation rendering, cost estimation, and energy analysis.

Dedicated BIM analysis and performance tools are designed specifically for building-sustainability analysis, including energy-efficiency assessment, code compliance, selection of building orientation through solar analysis, and construction sequencing. These programs simplify the implementation of sustainable-building projects across their different stages. Building Performance Analysis tools use latitude, longitude, and solar orientation to determine the building's actual orientation and contribute to its sustainability performance [5].

Solar-analysis software can identify an optimal building orientation for the use of natural lighting, significantly reducing the demand for artificial lighting and the resulting heat gain. To maximize these benefits, natural lighting must be analyzed efficiently and its characteristics assessed accurately. Proper daylight provision depends on building orientation, envelope configuration—including the position of glazing, materials, and construction assemblies—and building massing [6]. Compatibility tools are connected to BIM through interoperability, enabling information exchange between applications that support sustainable design. Industry Foundation Classes (IFC), developed by the International Alliance for Interoperability, provide a standard mechanism for data exchange and integration among these tools.

2.3 Shadow Analysis and Its Impact

Shadow analysis is a critical element in building design because it affects energy efficiency, natural lighting, and material performance. It helps explain how building form and orientation influence energy consumption and daylight availability [7]. Integrating shadow analysis into BIM models enables a detailed assessment of how shadows affect material performance over time [8].

3. METHODOLOGY

This study is based on a case study of a residential building in Basilia City, selected because of its design criteria and the materials used. The modeling process began with Revit 2023, in which a three-dimensional model was created to encompass all design details and materials. Accurate data on the physical and chemical properties of the materials were entered into the model. Shadow analysis was then performed using the program's tools to assess the effect of shadows cast by architectural elements on energy and material efficiency.

Natural lighting was evaluated with Revit Insight 2025 to study its distribution within the building and the effect of the selected materials on lighting quality and efficiency. The environmental analysis integrated the results of material modeling, shadow analysis, and natural-lighting assessment to determine how building sustainability could be improved through modifications to material design and distribution. Data were collected from the BIM model and analyzed using integrated analysis tools, and the results were reviewed and compared against environmental standards. The study encountered limitations related to data accuracy and the integration of the different analyses; these were addressed through advanced analytical techniques and alternative solutions as needed.

4. CASE STUDY: EA-189, BASILIA CITY

4.1 Design and Research Methodology

The study centers on EA-189 in Basilia City, Damascus, specifically in the Kafarsouseh district. The methodology includes:

- modeling with Revit 2023;
- shadow analysis to assess its impact on building materials; and

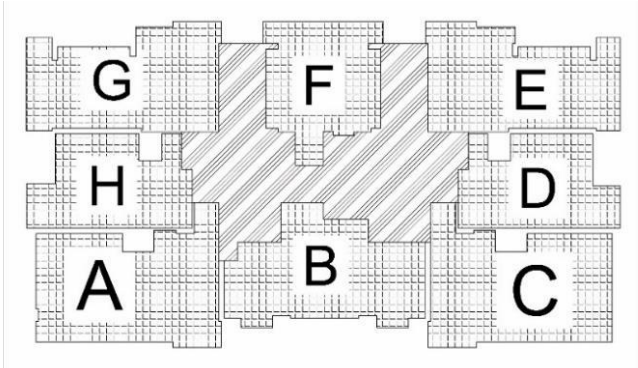


Figure 1. Number and distribution of apartments on a typical floor. Source: General Company for Studies.

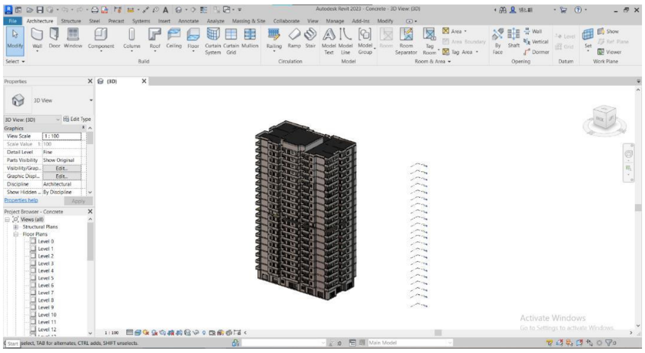


Figure 2. Building modeling process within Revit. Source: Researcher.

- evaluation of natural lighting facilitated by the building envelope and its interaction with construction materials using Revit Insight 2025 and Lighting Energy.

This structured approach ensures a thorough investigation of sustainable building practices using BIM technologies and contributes to architecture and sustainable urban development.

EA-189 is a residential tower comprising a ground floor, 19 typical floors, a technical floor, and four basements. Its areas and heights are:

- ground floor: 847 m^2, 4.75 m high;
- typical floor: 947 m^2, 3.40 m high;
- technical floor: 862 m^2, 2.80 m high; and
- basements: 1900 m^2 each, including the entire tower area, 3.40 m high.

Each typical floor contains eight residential apartments, as illustrated in Figure 1.

4.2 Data Collection Tools

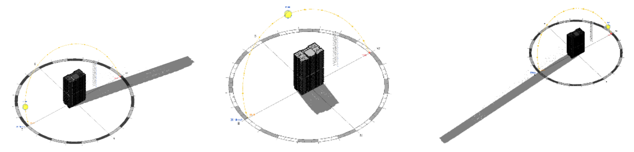
Engineering drawings of the studied building were provided in DWG format by the General Company for Studies in Damascus. These drawings formed the basis for modeling the building in Revit.

4.3 Data Analysis

Figure 2 shows the completed building model within the Revit environment.

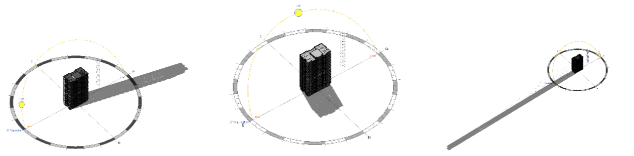
4.4 Shadow Study and Its Impact on Building Materials

Fundamental criteria for sustainable construction include optimal climate compatibility, effective reduction of energy



(a) 7:00 a.m. **(b)** 12:00 p.m. **(c)** 5:00 p.m.

Figure 3. Simulated shadows during the spring season. Source: Researcher.



(a) 7:00 a.m. **(b)** 12:00 p.m. **(c)** 5:00 p.m.

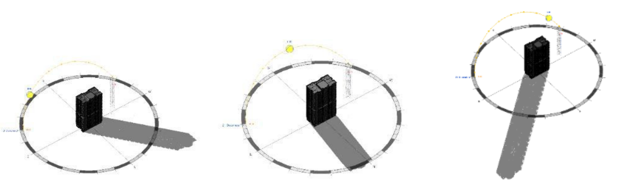
Figure 4. Simulated shadows during the summer season. Source: Researcher.

consumption, and a commitment to sustainability. Buildings should therefore be designed and executed according to standards that reduce reliance on fossil fuels and depletable energy sources. Construction must place significant emphasis on renewable natural resources, particularly solar energy.

Shadow analysis for the building was conducted during four periods in 2030—March, June, September, and January—from 7:00 a.m. to 5:00 p.m. The project's geographic location was first determined using the Location command, ideally with internet connectivity for precise positioning. Sun settings and shadows were then simulated for spring at 7:00 a.m., 12:00 p.m., and 5:00 p.m. (Figure 3); summer at the same times (Figure 4); autumn at the same times (Figure 5); and winter at 9:00 a.m., 12:00 p.m., and 3:00 p.m. (Figure 6).

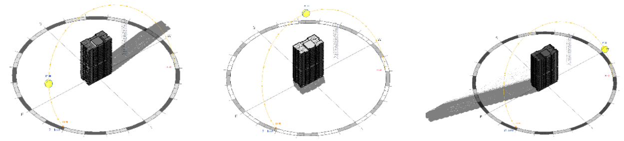
The study emphasizes the profound impact of direct sunlight on the roof and east–west facades, which collectively comprise 33% of the building envelope's total facade area. Despite this exposure, the building's predominantly north–south orientation minimizes these areas relative to its overall size. Aligning a building in a north–south direction offers numerous advantages, particularly for sustainable architectural design and energy efficiency. It facilitates balanced natural lighting throughout the day: east and west facades receive morning and afternoon sunlight respectively, while the north and south facades benefit from a more consistent distribution of natural light. This reduces reliance on artificial lighting [9].

Moreover, the north–south orientation helps control temperatures by minimizing direct sunlight exposure on the east and west facades. It therefore decreases the need for air conditioning, contributing to lower energy consumption and operational costs [10]. The choice of building materials and



(a) 7:00 a.m. **(b)** 12:00 p.m. **(c)** 5:00 p.m.

Figure 5. Simulated shadows during the autumn season. Source: Researcher.



(a) 9:00 a.m. **(b)** 12:00 p.m. **(c)** 3:00 p.m.

Figure 6. Simulated shadows during the winter season. Source: Researcher.

their response to orientation and sunlight exposure is crucial for regulating thermal transmittance and maintaining a comfortable indoor environment. Materials with high thermal mass, such as brick or stone, store heat during the day and release it at night, contributing to indoor temperature regulation [11].

Materials with high thermal resistance and sustainable sourcing practices further enhance the environmental performance of the building over its lifetime. Integrating effective shading strategies and maximizing natural lighting not only improves energy efficiency but also enhances visual comfort and indoor air quality [6]. In conclusion, strategic building orientation and thoughtful material selection are pivotal in mitigating solar impacts, improving energy efficiency, and fostering a sustainable and comfortable indoor environment. By orienting buildings north–south, architects and designers can optimize natural resources such as sunlight and shading systems, thereby creating healthier and more cost-effective living spaces for occupants.

4.5 Natural Lighting, the Building Envelope, and Materials

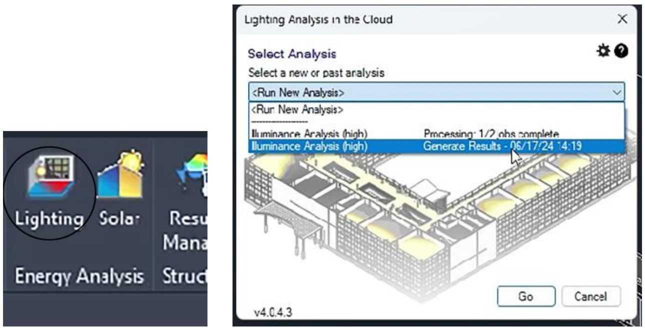
Building materials play a crucial role in determining natural-light levels inside buildings. They can be grouped into two main categories:

- **Transparent materials:** This category includes glass, some types of plastics, and other materials that allow sunlight to pass through. Using transparent materials in building design maximizes the utilization of natural light within indoor spaces, reducing the need for artificial lighting during daylight hours and contributing to energy savings. They can also enhance the psychological state and productivity of users by providing a visual connection to the outdoor environment.
- **Opaque materials:** These materials do not allow light to pass through and include most types of brick, stone, concrete, and insulation materials. Opaque materials are essential for providing privacy, security, and thermal insulation. However, careful planning is required when distributing them within the building to ensure a balance between privacy and protection while still providing sufficient natural lighting.

4.6 Lighting Analysis of the Studied Building

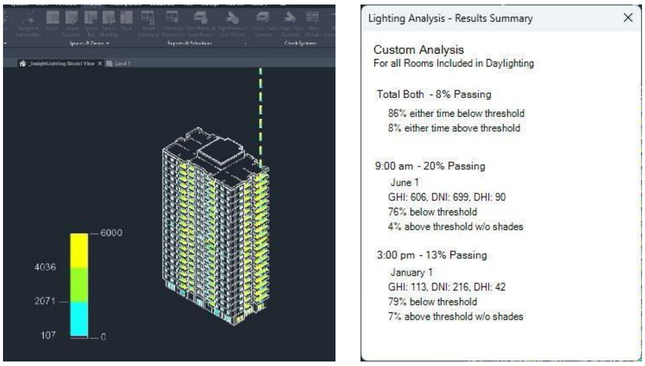
After adjusting the site and sun settings, "Lighting" was selected from the Insight 2025 menu and the analysis settings were configured as shown in Figure 7. The analysis was then run, producing color-coded three-dimensional and analytical results (Figure 8).

The results highlight several findings regarding natural lighting. Global Horizontal Irradiance (GHI), which measures



(a) Lighting command. (b) Analysis settings.

Figure 7. Lighting settings within Insight 2025. Source: Researcher.



(a) Three-dimensional result. **(b)** Analytical summary.

Figure 8. Results of the lighting analysis within the building. Source: Researcher.

total solar irradiance on a horizontal surface, and Direct Normal Irradiance (DNI), which measures direct solar irradiance without reflection or scattering, are important indicators of solar potential. Diffuse Horizontal Irradiance (DHI) represents solar irradiance scattered in the sky.

Overall, only 8% of the measured times or areas meet the required natural-lighting standards. This low percentage suggests inadequacies in the current building design or distribution of natural lighting. At 9:00 a.m., only 20% of measurements exceeded the specified threshold, indicating suboptimal lighting conditions in most areas. At 3:00 p.m., only 13% surpassed the required threshold, also highlighting substantial deficiencies.

A predominant 86% of measurements fall below the required threshold across different times, emphasizing widespread insufficiency. Conversely, 8% of areas exceed the threshold, potentially leading to excessive heat due to over-illumination. These findings underscore the need to optimize daylight strategies in building design to enhance energy efficiency and occupant comfort while mitigating overheating.

4.7 Lighting on the Repeated Floor and Interior Spaces

The repeated floor plan was isolated to observe the effect of lighting on interior spaces in greater detail, as shown in Figure 9. Figure 10 identifies interior spaces with weak natural lighting.

Areas highlighted in blue on the floor plan indicate very weak natural lighting. The analytical tools showed that the required daylight standards were not achieved. The following solutions are proposed:

Figure 9. Percentage of natural lighting and its impact on interior spaces. Source: Researcher.

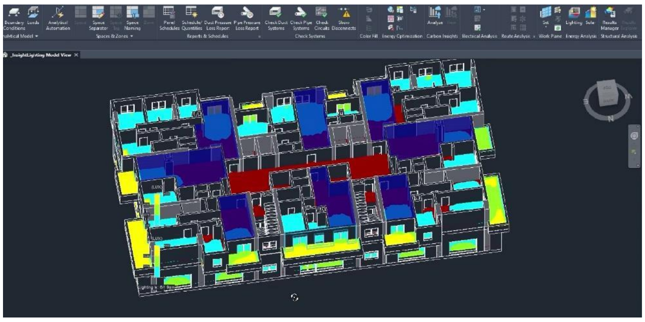


Figure 10. Interior spaces with weak natural lighting. Source: Researcher.

1. **Increase floor heights:** Increasing the vertical distance between floors can reduce shading from upper floors onto lower ones and maximize the use of natural light.
2. **Increase the proportion of transparent materials:** Increasing the ratio of facade glazing, with taller windows extending from floor to ceiling, can admit more natural light and provide a wider field of vision.
3. **Use light-reflective elements:** Reflective surfaces or materials on interior or exterior facades, or beneath windows, can redirect natural light indoors.

4.8 Results of the Practical Simulation

The construction sector contributes significantly to annual environmental degradation. Sustainability practices extend the productive lifespan of buildings while saving energy, money, and materials. Green buildings aim to maintain a balance between a building and its surrounding environment, protecting inhabitants from climatic conditions without harming the environment or depleting resources and ensuring that future generations retain access to their fair share. Green-building techniques substantially reduce global carbon emissions.

The production of building materials must improve in efficiency and effectiveness because it has a major impact on the surrounding environment. The use of building technology is crucial for designing green buildings, focusing on building-operation systems, reducing energy consumption, and providing thermal comfort for users. These measures enhance overall building efficiency.

For the residential building in Basilia City, the results highlight the importance of building orientation and effective design in minimizing unwanted thermal effects and enhancing residents' environmental comfort. Shading and sunlight play a crucial role in influencing energy consumption and thermal comfort inside the building. Proper orientation successfully reduced thermal loads during the hottest months.

The strategic use of transparent and opaque materials improved natural-lighting levels while maintaining comfortable temperatures and reducing reliance on artificial lighting. Insulating materials significantly affected thermal insulation by reducing unwanted heat transfer and thereby lowering cooling and heating energy consumption. Careful selection of building materials contributed substantially to a comfortable indoor environment. The study indicated that materials with low thermal conductivity reduce excessive heat transfer indoors, leading to higher energy efficiency. Replacing conventional building materials with sustainable alternatives reduced the building's carbon footprint. Intelligent material use can therefore enhance the building's overall level of sustainability.

4.9 Recommendations from the Practical Simulation

The study recommends encouraging the proper use of sustainable green-building materials and promoting sustainability awareness among key players in the construction market—owners, consultants, contractors, and companies—through public lectures, training courses, studies, and research. Government intervention is crucial through the development of mandatory local regulations and the implementation of sustainable practices in all types of buildings. Companies and institutions in the construction sector should begin using sustainable and green materials to improve building processes. The use of energy-modeling programs should also be encouraged to achieve energy efficiency in the built environment.

For the residential study in Basilia City, the sustainability assessment should be extended to include all buildings within the city. Precise design approaches should account for the effects of shading and sunlight. Building materials should be selected to achieve thermal balance and improve natural lighting. Regular evaluations of the thermal performance of the materials should be conducted, together with continuing research to develop new materials that reduce carbon emissions and reflect sustainability principles.

5. DISCUSSION

This study examines the impact of building-material modeling on enhancing sustainability through a case study of a residential building in Basilia City. Data analysis indicates that modeling the building using Revit 2023 was effective in determining how shadows and natural lighting affect its environmental performance. Shadow analysis was conducted at different times of the year—March, June, September, and January—to observe the effects of shadows on the building's east and west facades. The results showed that the north–south orientation reduces adverse solar effects on material energy efficiency. The north and south facades benefit from balanced natural-light distribution, reducing reliance on artificial lighting and lowering cooling costs.

Building materials play a crucial role in determining natural-light levels inside the building. They were categorized as transparent or opaque. Transparent materials such as glass increase the entry of natural light and reduce the need for artificial lighting, thereby enhancing user comfort.

Lighting-analysis results from Revit Insight 2025 showed that natural-lighting levels fail to meet the required standards in most areas. Only 8% of measurements exceeded the specified daylight threshold, indicating deficiencies in the current building design or natural-light distribution. The study therefore recommends increasing floor heights, increasing the proportion of transparent facade materials, and using light-reflective elements to improve natural lighting.

The study also indicates that solar energy is a powerful renewable resource with a significant effect on building sustainability and efficiency. Dark-surfaced materials absorb more solar energy and heat more readily, while light-surfaced materials reflect more light and help maintain moderate indoor temperatures. In addition, materials with good thermal insulation reduce the need for heating and cooling, thereby lowering energy consumption.

6. CONCLUSION

6.1 Summary of Key Findings

This study provides significant insights into the impact of modeling building materials on enhancing sustainability through the use of Revit 2023. The shadow-analysis results revealed that the north–south orientation of the building plays a crucial role in improving natural-light distribution and reducing the effects of shadows on energy efficiency. This orientation helps decrease reliance on artificial lighting and reduce cooling costs. The study also found that using materials with high thermal mass, such as brick and stone, helps regulate indoor temperatures by storing heat and releasing it at night, thereby improving the building's environmental performance.

Regarding natural lighting, the study demonstrated that the materials used in the building envelope significantly affect the level of illumination inside the building. Transparent materials, such as glass, increase natural-light entry and reduce the need for artificial lighting, enhancing user comfort. In contrast, opaque materials provide privacy and thermal insulation, but careful planning is required to balance these factors and ensure adequate natural light.

Results obtained using Revit Insight 2025 indicated that natural-lighting levels in many areas do not meet the required standards, highlighting the need for improved building design and natural-light distribution. The study recommends increasing floor heights, increasing the proportion of transparent materials in facades, and using light-reflective elements to improve natural lighting. Overall, the findings underscore the importance of optimal design orientation and appropriate material selection in enhancing building sustainability by improving the balance among shadows, natural lighting, and energy efficiency.

6.2 Concluding Remarks

The study emphasizes the importance of strategic orientation and careful material selection in reducing solar impacts and improving energy efficiency, thereby contributing to comfortable and sustainable indoor environments. It recommends extending sustainability assessment to all buildings in Basilia City, adopting precise design approaches that consider the effects of shadows and natural lighting, and updating material choices to achieve thermal balance and improve natural lighting.

Furthermore, the study advocates promoting the use of sustainable green materials and increasing sustainability awareness among all stakeholders in the construction sector through lectures and training courses [12]. Government intervention is also necessary through the development of local regulations and the incorporation of sustainability practices into all building types. In addition, the use of energy-modeling programs should be encouraged to achieve energy efficiency in the built environment [13].

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