Adapting Traditional Sustainable Architectural Elements in Modern Buildings Utilizing Modern BIM Technologies

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Abstract

This study aims to explore the role of traditional architectural elements in promoting sustainability and how to integrate them into modern buildings by utilizing modern technologies, especially Building Information Modeling (BIM), to restore heritage identity and apply green building standards to modern residential buildings. Despite the advancements in modern urban and architectural developments, sustainability is an ancient concept. Traditional architecture in our region has successfully balanced the use of natural resources with environmental preservation, thereby providing cultural and environmental identity to heritage buildings. In Aleppo, modern residential buildings suffer from a loss of this deep connection to the environment and authentic identity. This research employs BIM software to model and analyze the heritage house of Ajqabash, assessing its compliance with green building standards. The study highlights the role of modern BIM technologies in facilitating environmental analysis and emphasizes the importance of traditional elements, such as the iwan and the internal courtyard, in providing thermal comfort for residents. By studying and analyzing traditional architectural elements and using BIM techniques, the article demonstrates that the concept of sustainability is deeply rooted in our architectural heritage. The Revit program was utilized to model the Ajqabash house in its architectural and structural details, and an energy simulation plug-in was used to analyze the sun's impact on the house. The findings underscore the effectiveness of BIM in conducting environmental studies and in preserving heritage while promoting sustainability. The goal is to develop new design criteria that combine heritage architectural identity with global sustainability standards. This approach aims to contribute to building environmentally and economically sustainable architectural communities and providing innovative solutions to modern housing problems in Aleppo. Ultimately, the research seeks to honor our rich architectural heritage while addressing contemporary environmental challenges.

Keywords: Sustainable Heritage Elements; Green Buildings; Sustainable Architecture; Green BIM; HBIM; Architectural Heritage Elements

1. Introduction

In the context of pressing global environmental challenges such as climate change, ecosystem degradation, and the depletion of natural resources, the imperative for sustainable architectural solutions that prioritize environmental efficiency has never been more pronounced. This is supported by recent studies highlighting the transformative potential of integrating modern technologies, such as Building Information Modeling (BIM), with traditional architectural elements to restore and enhance sustainability in urban settings [1, 5, 10]. Sustainable architecture and green building practices represent a critical response to these challenges, aiming not only to create healthier and more sustainable living environments but also to uphold ecological and economic balance. Throughout history, architects have innovatively utilized techniques to adapt to environmental conditions and control the internal environments of buildings. Traditional architecture in various regions has demonstrated a

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remarkable ability to achieve harmony between utilizing natural resources and preserving the environment, thereby imbuing heritage buildings with distinct cultural and environmental identities [3]. In today's rapidly evolving urban landscapes, however, many modern residential buildings, particularly in cities like Aleppo, have strayed from this ethos. Influenced by Western architectural trends and subjected to rapid urbanization, these structures often lack a meaningful connection to their environmental context and traditional heritage identity [3, 10].

Recent studies underscore the transformative potential of integrating modern technologies, such as Building Information Modeling (BIM), with traditional architectural elements to restore and enhance sustainability in urban settings. BIM, renowned for its capacity to simulate and analyze building performance throughout its lifecycle, offers a promising pathway to reconnect contemporary architectural practices with sustainable principles rooted in our heritage [1, 5, 10]. Research has shown that BIM can play a pivotal role in addressing challenges faced by the Architecture, Engineering, and Construction (AEC) industry globally. Articles exploring BIM's application highlight its effectiveness in optimizing project management, enhancing design efficiency, and promoting sustainability across various contexts [2, 4, 6].

For instance, studies have examined BIM's impact on historical building management, revealing how digital documentation and integrated BIM frameworks can streamline restoration processes and facilitate better collaboration among stakeholders [1, 9]. Furthermore, investigations into BIM's role in smart sustainable cities underscore its potential to integrate AI, IoT, and lean construction practices, thereby improving operational efficiency and environmental performance [2].

In countries like Syria, where BIM adoption remains nascent, research efforts are focused on overcoming barriers to implementation. Studies emphasize the importance of raising awareness, assessing industry readiness, and addressing organizational capabilities to harness BIM's full potential in transforming AEC practices and achieving national development goals [7, 11]. Moreover, amidst global health crises like the COVID-19 pandemic, research highlights the urgent need to integrate BIM with enhanced safety protocols to mitigate risks in construction environments and safeguard people health [8].

In conclusion, by embracing the intersection of traditional architectural and cutting-edge technologies like BIM, stakeholders in the AEC industry can pave the way for more sustainable and resilient urban environments. This research seeks to advance this vision by proposing methodologies to implement BIM effectively in regions like Aleppo, thereby revitalizing architectural heritage and contributing to a sustainable future.

2. Literature Review

2.1 BIM: Building Information Modeling (BIM) is fundamentally about creating manageable and shareable representations of both physical and functional data that define buildings over their entire life cycles in digital formats [13, 14]. Despite this broad definition, the exact nature of BIM remains subject to varied interpretations and definitions [12, 15, 16]. For instance, [17] defines BIM as "a modeling technique and associated processes for producing, communicating, and analyzing building models," whereas [18] offers a slightly different perspective, describing it as "a methodology for managing essential building design and project data digitally throughout the building lifecycle."

BIM technology continues to evolve, offering increasingly detailed information and models that extend beyond traditional concerns such as cost and time to encompass energy consumption and collision detection [20]. This evolution arises from the inadequacy of traditional 2D and 3D CAD diagrams, which lack the capacity to handle the vast amounts of information necessary for modern construction projects. Traditional CAD tools often omit crucial data such as tender details, schedules, and materials [19].

Unlike mere computer software, BIM represents an integrated process leveraging various technologies. It fosters collaboration among diverse professionals in a multidisciplinary environment, facilitating information sharing and cooperation. This collaborative approach streamlines workflows compared to traditional methods, resulting in fewer errors and faster, more cost-effective project completion. Moreover, BIM transcends being merely a modeling tool; it embodies a holistic process that integrates and coordinates all stakeholders throughout every phase of a building's life cycle.

2.2 HBIM: Historical Building Information Modeling (HBIM) represents an advanced information management strategy [1] designed to enhance the efficiency of maintaining and restoring historical buildings. It leverages information technology to develop detailed 3D models that encompass critical data such as construction history, materials, and specifications.

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2.3 BIM Role in Heritage Conservation:

Importance of HBIM for Built Cultural Heritage

HBIM plays a crucial role in digitally representing the physical and functional characteristics of historical buildings across their lifecycle stages, including additions, modifications, restoration, and maintenance [1]. By developing precise 3D digital models, HBIM captures the original design, structure, and materials of historical buildings with high accuracy. This detailed documentation aids in analyzing the current condition of buildings, identifying potential damage, and planning appropriate interventions [21].

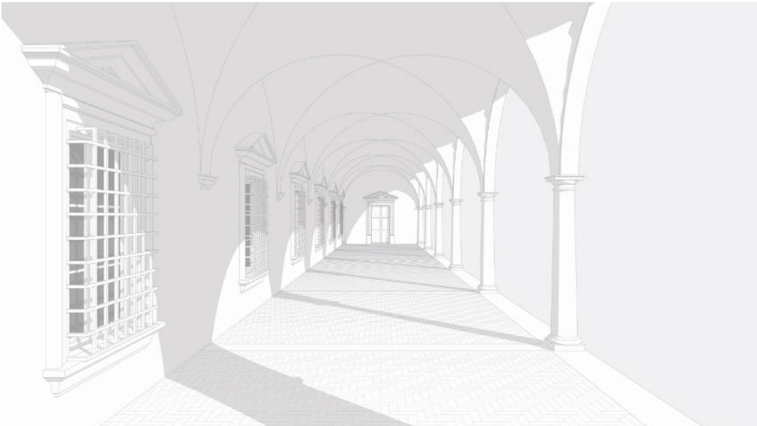

Figure 1. HBIM

Applications of HBIM in Maintenance and Restoration

BIM technology offers several practical applications that significantly enhance the efficiency and effectiveness of maintenance and restoration operations for historical buildings:

1. **Accurate and Comprehensive Information**: Specialized HBIM software enables the analysis and documentation of precise information about buildings, their components, and systems. This detailed data is essential for informed decision-making and effective management of historical buildings [22].
2. **Data Analysis and Predictions**: HBIM allows for the analysis of building data to predict potential outcomes of changes, facilitating better decision-making and efficient planning of maintenance and renovation activities. Proactive identification and mitigation of risks help minimize potential damages [22].
3. **Enhanced Collaboration and Coordination**: By fostering communication and collaboration among stakeholders involved in managing historical buildings, HBIM facilitates seamless sharing of models and data. Improved coordination ensures a smooth workflow and efficient building management [23].
4. **Improved Cost Efficiency**: Utilizing specialized HBIM software optimizes cost efficiency by accurately analyzing data and predicting maintenance issues. This proactive approach helps prevent costly damages and reduces overall maintenance expenses in the long term [24].

2.4 BIM Role in Sustainability and Environmental Design:

1. **Comprehensive Project Visualization and Analysis**: BIM enables project teams to visualize sustainability aspects from the early design stages through project completion. It provides a range of benefits that contribute to improving construction efficiency both environmentally and economically.
2. **Improved Project Scheduling**: BIM simplifies project scheduling and enhances cost-effectiveness. By integrating scheduling information into the digital model, coordination and sequencing of activities are optimized, leading to more efficient scheduling and timely project completion.
3. **Enhanced Design and Execution Quality**: BIM helps improve the quality of design and execution by creating detailed 3D models of architectural, structural, mechanical, and electrical components. This allows stakeholders to evaluate designs more effectively before construction begins, reducing errors in later stages and enhancing collaboration and coordination among different teams.

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4. **Enhanced Collaboration and Communication**: BIM provides a central platform for real-time collaboration among architects, engineers, contractors, and other team members. This simplifies communication and strengthens a more integrated approach to sustainable design and construction. Effective decision-making, task coordination, and problem-solving contribute to better project outcomes.
5. **Improved Energy Analysis and Simulation Capabilities**: Professionals can conduct detailed energy analyses and simulations using BIM to evaluate different design alternatives and assess their impact on energy efficiency. This includes analyzing solar gain, thermal performance, and daylighting strategies, aiding in the identification of the most effective strategies for reducing energy consumption and achieving sustainability goals.
6. **Effective Resource Management and Waste Reduction**: By creating detailed 3D models, BIM improves the accuracy of material quantities estimation and resource requirements. This analysis helps in planning material use and identifying potential conflicts and wastage, thereby promoting sustainability by reducing environmental impact and waste disposal costs. [25]

2.5 Benefits of Building Information Modeling (BIM) in Achieving Sustainability

The comprehensive approach of BIM allows project teams to visualize, analyze, and enhance sustainability aspects starting from the early design phases through to project completion. By integrating sustainable design and construction practices throughout the project lifecycle, BIM contributes to:

- **Improved Project Management**: BIM enhances project management, performance tracking, and maintenance management more effectively, extending the building's lifespan and reducing the need for early reconstruction.
- **Long-term Sustainability**: With the broader adoption of BIM, significant improvements can be achieved in managing renewable resources and the long-term sustainability of construction projects. This marks a true transformation towards more sustainable and professional building environments for future generations.

In conclusion, Building Information Modeling (BIM) emerges as a key driver in propelling the construction industry towards a more sustainable and efficient future. It contributes to enhancing all aspects of the construction process from planning to execution and maintenance, creating healthier and sustainable built environments for future generations.

Figure 2. Green BIM

a. Heritage Architectural Elements:

1- Dense Urban Fabric: The dense urban fabric of the old city provides shade, contributing to energy conservation, and adds an aesthetic touch to the city through the contrast between sunny and shaded areas created by the varying surfaces and protrusions.

2- Inward Orientation: This design ensures complete privacy and independence, while also providing climate protection and defensive security.

3- Broken Entrances: These are designed for social considerations to prevent passersby from seeing inside the house, and for environmental considerations as well. As air moves through the broken entrance and collides with its walls, it is cleansed of dust and particles. Additionally, the broken entrance creates an intermediate pressure zone between the streets and the interior courtyards, facilitating natural and automatic airflow to and from the building [26]

4- The Inner Courtyard: The traditional residential design relies on the inner courtyard as a central point to achieve the principle of introversion. The courtyard serves as an open space that helps cool the interior spaces. It is a key element of traditional architecture in hot climates, reducing fuel consumption and relying on natural ventilation. The courtyard facilitates the entry of cool air inside, improving the indoor environment. Additionally, its structure can be adapted to produce a large amount of shade.

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The accompanying image illustrates the airflow within the courtyard during day and night:
"The inner courtyard acts as a thermal regulator by taking advantage of the significant temperature differences between day and night and creating varied pressure zones between the shaded narrow streets and the open central courtyard. At the beginning of the day, the central courtyard retains the cool air it accumulated during the night and remains partially or fully shaded, providing a comfortable area for the residents. As the sun rises and temperatures increase, the materials in the courtyard quickly absorb heat, making it resemble a thermal chimney. However, the shaded alleys remain cool, creating high-pressure zones that push cool air through openings in the house walls from the alleys to the central courtyard via the still cool interior spaces. This phenomenon is due to the thermal lag properties of the building materials, which delay the rise in temperature by about 10-12 hours. The thermal movement was further exploited through organized airflow between variously sized courtyards or through corridors connecting the central courtyards and their deep cellars. In the evening and night hours, residents use the rooftops for sitting and sleeping, as the courtyard and thick walls begin to radiate the heat stored throughout the day. Cool air gradually descends into the central courtyard, creating what is known as 'night flushing. [27]

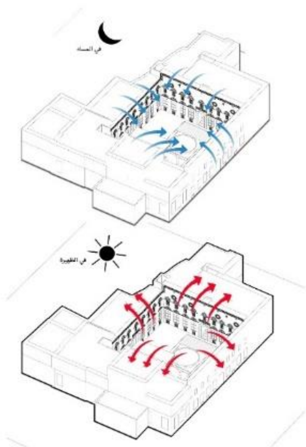

Figure 2. Courtyard in Ajaqbash house

5- The iwan: The iwan is completely open to the inner courtyard and serves a main function in the dwelling, especially on summer days, for seating and reception. It is usually located on the southern side of the houses. It is surrounded by three walls and a ceiling supported by columns decorated with arabesque designs. The iwan's mission is to receive guests during the summer months, because it is open from the north, so it is a cool place. The iwan is located on an elevated area of 24 to 40 cm in relation to the floor of the house. The main wall of the iwan usually includes a mihrab with arches, arches, and other decorative forms. On either side of the iwan, two symmetrical rooms are usually located.

Figure 3. Iwan in Ajaqbash house

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6- Openings and windows: Limiting the use of external openings and making them small has an effect in maintaining the internal temperature without being affected by the high external temperature during the day in the summer and its low at night, and vice versa in the winter. Two levels of windows were also used in Arab houses, upper and lower, and this design played a role in refreshing the air in the rooms**.**

7- The wind catcher (Malqaf): is an air well above the building, which includes an opening facing the direction of the prevailing winds to capture the air passing over the building, which is usually cooler, and then push it into the building. The shapes of the Malqaf vary according to the number of upper openings in them. The wind catcher has important benefits, including: - Effective ventilation: The wind catcher eliminates the need for large windows to provide ventilation.

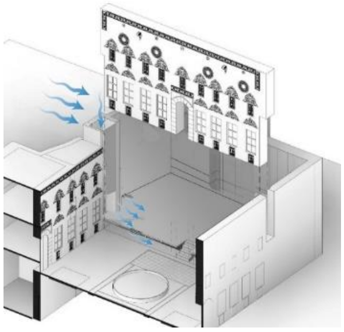

Figure 4. The wind catcher in Ajaqbash house

- Reducing dust and sand: It helps reduce the entry of dust and sand in hot and dry areas.

- Thermal comfort: It contributes to improving thermal comfort in warm, humid regions that depend on air movement, especially in adjacent buildings that do not allow the wind to pass through and where windows are insufficient. Al-Malqaf can be developed to enhance the use of renewable energy such as wind energy.

8- The Mashrabiya / Screened Balconies: The mashrabiya is a distinctive architectural element that serves several important functions in traditional architecture. Its primary functions include:

Figure 6. Mashrabiya in Farhat Square

-Indirect Light Introduction: The mashrabiya allows large amounts of indirect light to enter, providing effective illumination without increasing interior temperatures.

-Blocking Direct Solar Radiation: It blocks direct solar radiation, which is often accompanied by high temperatures, thus keeping the rooms cooler.

-Enhancing Airflow and Ventilation: The mashrabiya improves airflow within rooms, increasing ventilation and cooling.

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-Temperature Regulation in summer and winter: It prevents direct heat gain from sunlight and allows a constant airflow to cool the interior in summer, while in winter, it allows sunlight to enter, warming the rooms.

-Controlling Airflow: The mashrabiya features openings of various sizes; narrow openings provide light and reduce glare, while larger openings increase airflow. The lower part of the mashrabiya consists of narrow latticework, and the upper part of wide latticework, ensuring a balance between lighting and ventilation.

-Increasing Air Humidity: The air humidity can be increased by placing clay jars in the mashrabiya, where the airflow is cooled by evaporative cooling. Additionally, the wood used in the mashrabiya absorbs moisture at night and releases it during the day.

-Providing Privacy: The mashrabiya offers privacy for the residents while allowing them to look outside, making them feel connected to the outside world without losing their privacy.

The mashrabiya combines functional efficiency with aesthetic and social value, making it a unique and sustainable architectural element in traditional houses.

9-The Fountain: The fountain is placed in the centre of the courtyard of the house and is used only in areas with a hot, dry climate. It can be circular, octagonal, or hexagonal in shape. The purpose of the fountain is to enhance the aesthetic appearance of the courtyard, mix the air with water, and humidify it before it moves into the interior spaces. The water increases the humidity in the air and helps to lower the air temperature because as hot air passes over the surface of the water, the water evaporates, absorbing a significant amount of heat from the air, thereby reducing the temperature. Additionally, it acts as a sound barrier to noise, producing a continuous low sound that attracts the ear away from the noise.

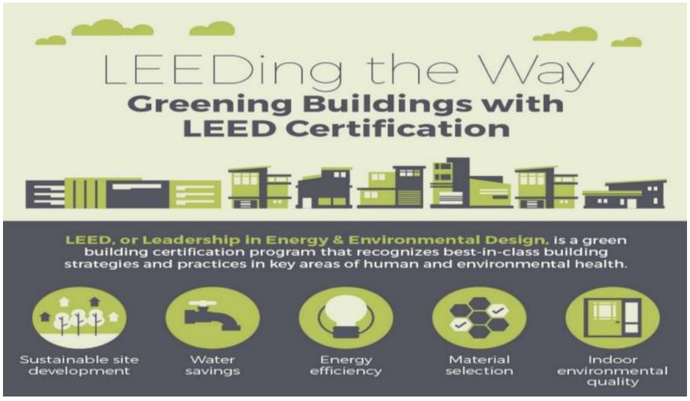

Figure 5. LEED requirements

10-Salsabil: Some old houses in Aleppo contain architectural elements known as "Salsabil" or "Sabeel," which are traditional water systems used to cool and refresh the air inside the homes. Salsabils consist of water passages that run through the houses, where water flows gently along the surface or walls, helping to cool the surrounding air and increase humidity in the indoor environment. This is an example of innovative design in old houses to cope with harsh climatic conditions and achieve thermal comfort for the inhabitants.

11-The Feskieh: The feskieh is a water basin used for watering plants. It is usually circular in shape and typically tiled with white marble. It supports the concept of water efficiency in green houses.

12- Solar Breakers: Solar breakers, traditionally made from wooden shelves and projections supported by cables, were used to provide protection from rain and to reduce the amount of sunlight hitting the building facades

13- Ornamental Decorations: Arab architects enriched all architectural elements of the house with botanical, geometric, and calligraphic decorations, which distinguished the Arab Islamic residence and gave it a unique character. The inclusion of ornamental decorations plays a significant role in highlighting architectural identity.

b. Basic Requirements for Green Building Certification: [25]

1. Site Efficiency:

- **Proximity to Public Transport**: Choosing a site close to public transportation to reduce car usage.
- **Preservation of Green Spaces**: Protecting green areas and sensitive natural zones.
- **Encouraging Physical Activities**: Designing spaces to promote walking and cycling.

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2. Energy Efficiency and Management:

This point aims to improve energy efficiency and reduce reliance on non-renewable sources:

- **High-Efficiency Building Design**: Using insulating materials and modern techniques for energy-efficient buildings.
- **Renewable Energy Use**: Utilizing renewable energy sources such as solar and wind power.
- **Energy Management Systems**: Monitoring and analyzing energy consumption.

3. Materials and Resource Efficiency

Focus on sustainable use of resources:

- **Sustainable Building Materials**: Using recycled and locally sourced materials.
- **Waste Reduction**: Minimizing waste through planning and design.
- **Material Reuse**: Reusing materials and reducing the use of natural resources.

4. Water Efficiency and Conservation:

This aspect aims to reduce water consumption and improve water resource management:

- **Water-Saving Fixtures**: Using low-flow faucets and toilets.
- **Rainwater Harvesting**: Collecting and using rainwater for irrigation or non-potable purposes.
- **Water-Efficient Landscaping**: Using native, drought-tolerant plants.

5. Indoor Environmental Quality:

This aspect relates to providing a healthy and comfortable indoor environment:

- **Indoor Air Quality**: Ensuring good ventilation systems and using low-emission materials.
- **Natural Lighting**: Utilizing natural light and designing indoor lighting for visual comfort.
- **Temperature and Humidity Control**: Providing a suitable indoor climate.

6. Operation and Maintenance:

This point includes ensuring building sustainability through effective operations and maintenance:

- **Routine Maintenance Plans**: Maintaining building performance through regular upkeep.
- **Training Staff**: Ensuring staff are trained to use building systems efficiently.
- **Sustainable Maintenance Techniques**: Reducing environmental impact through sustainable maintenance practices.

7. Waste Reduction and Recycling:

Focusing on minimizing waste and recycling:

- **Recycling Programs**: Implementing recycling programs within buildings to reduce landfill waste.
- **Waste Reduction Design**: Designing to minimize waste by reducing materials and packaging.
- **Recycled Materials Use**: Using recycled materials in the construction process.

Implementing these points helps improve building sustainability, reduce environmental impact, and enhance the quality of life for residents and users.

3. Research Methodology

Inductive Method: Through references and previous studies covering topics such as (traditional architectural elements in Islamic architecture, green buildings, environmental studies on traditional residential buildings, global standards and codes for green buildings, the uses of BIM in modelling heritage buildings, and environmental analyses 7D BIM...)

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Descriptive Method: Study of buildings that have obtained green building certifications and modern residential buildings that have incorporated traditional elements, to derive standards for modern construction.

Analytical Method: Modelling and analysing a traditional residential building from an environmental perspective using BIM applications, and comparing the results with green building standards.

4. Case Study: (Modeling and Environmental Analysis of the Heritage Ajqabash House and Its Compliance with Green Building Standards)

4.1. Historical and Architectural Overview of Ajqabash House:

4.1.1. Location

The house is located at the first Jasmine Gate in Al-Salibah in the Al-Jadida district, situated northwest of Aleppo outside the old city's walls. It is adjacent to two historical churches: Mar Assia Church for the Syriac Orthodox and the Forty Martyrs Church for the Armenians.

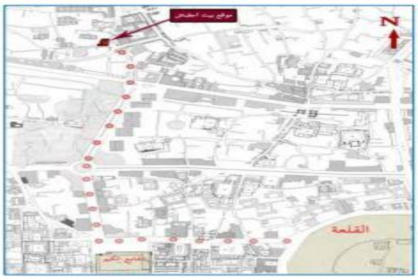

Figure 6. Location of Ajqbash House in relation to the citadel

4.1.2. Construction History:

The construction of Ajqabash House dates back to the Ottoman era. It was built by "Qara Ali,",in the 12th century Hijri, corresponding to the 18th century AD. Subsequently, the house became a communal residence for poor families, with each room rented out to a family. As a result, some rooms were divided by partitions that were removed during previous restoration efforts. The house was later converted into a museum for popular traditions. The Directorate General of Antiquities and Museums registered it as a historical building that must be preserved, and the museum was opened in 1982.

The eastern part of the house was cut off when the street leading from Al-Hatab Square to Bab Al-Qasab and Al-Kayali Avenue was widened, while retaining the internal facade without considering the historical value of the house. Like other houses in the eastern region of Aleppo, parts of the house suffered damage, as shown in the figure. Restoration of the house has begun under the supervision of the Directorate of Antiquities and Museums.

4.1.3. Architectural description:

Ajqabash House is distinguished by its rich and beautiful decorations that adorn the interior facades overlooking the courtyard, above the windows, and at the ends of the walls.

Figure 8. Baroque decorations

Figure 9. Baroque decorations

Figure 7. Baroque decorations

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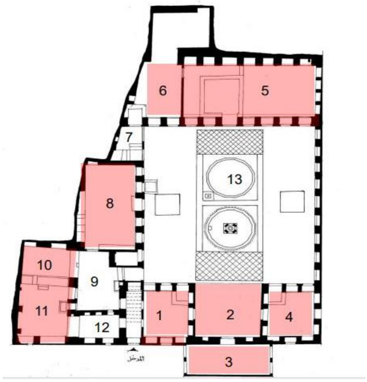

Figure 11. Ajaqbash plan

Figure 12. Muqarnas of the pointed arch

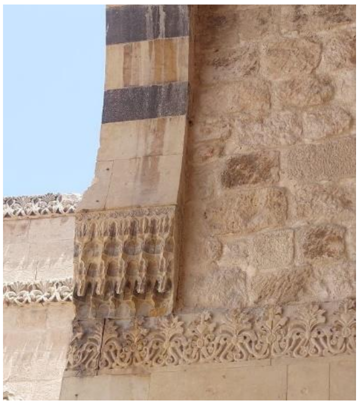

Figure 10. The Iwan of Ajqbash

The house features a modest and low-level entrance, and the interior courtyard is accessed via a stone staircase due to the difference in level between the street and the house's floor. The entrance leads us into a spacious and rich world with a wide courtyard containing a water basin surrounded by citrus and jasmine trees, and ornamental plants, reflecting the beauty of the internal environment of the traditional Arab house. This is a common feature in all traditional Arab houses in Syria.

Figure 13. The guest`s hall

The house includes an iwan, which is one of the most important architectural elements of the house. The iwan is a typical example, rising to two levels, and its floor is elevated by 40 cm above the courtyard level. Its ceiling consists of wooden beams, surrounded by inscriptions representing various wisdom sayings used in daily life. The pointed arch of the iwan, made of alternating stones (ablaq), rests on small muqarnas (stalactite-like decorations). We also find a wooden sunshade with beautiful geometric decorations.

Directly in front of the iwan is the main northern hall, also two stories high, which received meticulous care through its distinctive wooden ceiling, decorated walls, and a threshold paved with star-shaped marble pieces, in addition to furniture inlaid with mother-of-pearl. The southern wall of the room features two sets of windows, upper and lower, a special ventilation method aimed at continuously renewing the air. The alternating ablaq, using yellow and black stones, is also used in the openings overlooking the courtyard.

The sleeping quarters are located on the upper floor, known as the harem, while there is a basement accessible via stairs in the northeastern corner of the courtyard. This basement is roofed with intersecting vaults and has a central water basin. It is equipped with a ventilation shaft (malqaf) connected to the roof through the wall. This malqaf acts as a thermal mass storage, as the stones used in its construction remain insulated from sunlight due to their position within the wall, cooling down at night. During the day, when the air heats up due to the sun, the malqaf stays cool, cooling the air that enters it. Since cold air is heavier than warm air, it descends through the malqaf to cool the rooms. The water basin placed in front of the malqaf further cools the incoming air. There is also a rock-carved cave designated for storing provisions due to its low temperature. The construction of the house relied on limestone, as is the case with all houses in Aleppo, due to the availability and abundance of this material in the city and its surroundings.

The thickness of the house's walls varied; in the exterior walls and those overlooking the courtyard, the wall thickness reached 100 cm. The stone sections varied from 25x40x40 cm to 25x60x40 cm, and sometimes the course height was 30 cm. The wall thickness helped transfer the load of the ceilings to the house's foundations.

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Wooden elements were used in roofing and decorating the rooms, especially the main hall of the house, in addition to the panels used in covering the interior walls. These walls were decorated with poetic and Quranic inscriptions, along with drawings and gilded ornaments. The walls overlooking the courtyard received special attention with stone decorations, especially above doors and windows, reflecting the Baroque art that was prevalent during that period (the 18th century AD).

Figure 16. The wind catcher

4.2. Modeling Ajqabash House in Revit:

The modeling of Ajqabash House, a heritage site in Aleppo, follows these steps:

1- Preparation and Planning:

Gathering Information and Data:

1. Collect old photographs and plans of Ajqabash House, ensuring all relevant details are included.

2. Obtain architectural drawings from reliable sources like the Directorate of Antiquities and Museums, given the current function of the house as a museum of folk arts.

3. Visit the site to verify measurements and gather precise details.

Project Setup:

4. Open Revit and create a new project.

5. Set the measurement units to match those used in the AutoCAD drawings.

2- Creating Basic Components:

Creating Levels:

Define floor levels according to the architectural plans.

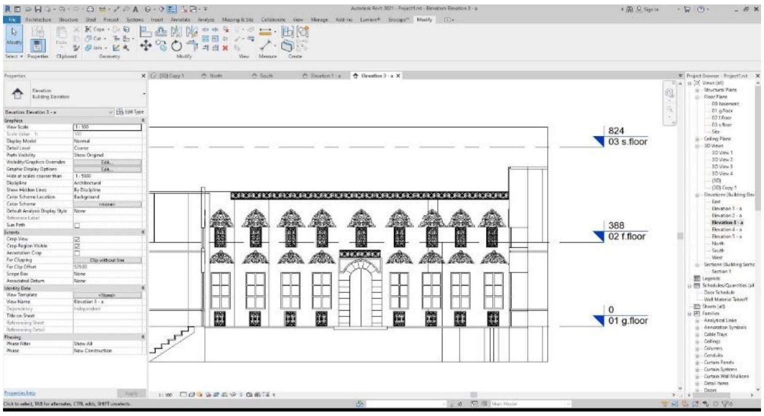

Figure 17. Setting up levels

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Building Walls:

- Use wall drawing tools to create interior and exterior walls of the house, specifying their thickness.
- Ensure the materials used in the walls align with traditional materials.

Adding Doors and Windows:

- Incorporate existing openings in the walls and convert them into blocks to optimize file size.
- Create families for similar elements within the house, categorizing materials for each family to facilitate file management and modifications.

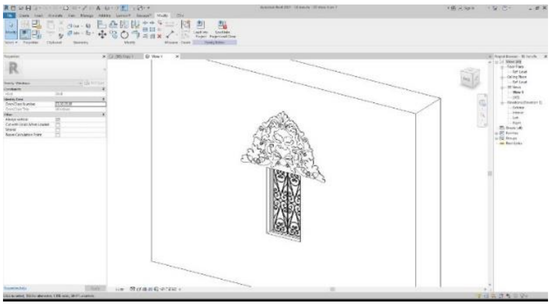

Figure 18. Window`s family

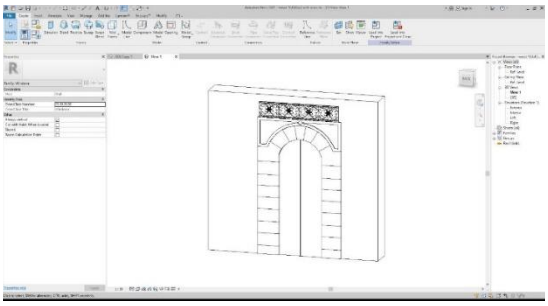

Figure 19. Door`s family

- **Detailing Interior and Exterior:**

1- **Roof Design:**

- Utilize Revit's roof tools to design the roof in accordance with traditional heritage styles.

2- **Adding Architectural Details:**

- Use available Revit tools to create arches, decorative elements, and thresholds.
- Use families to model architectural details accurately.

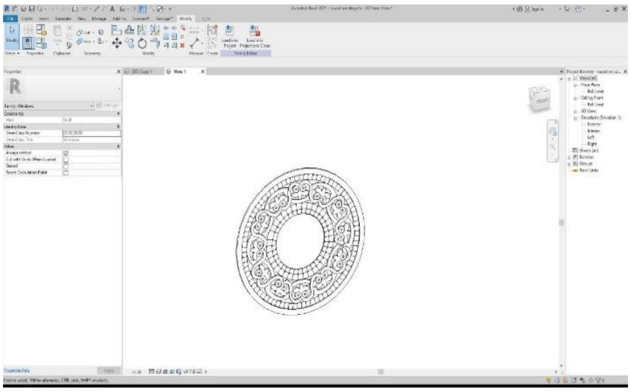

Figure 20. Decoration’s family

- **Output and Documentation:**

1- **Preparing 3D Views:**

- Set up various viewing angles to showcase the design in 3D.

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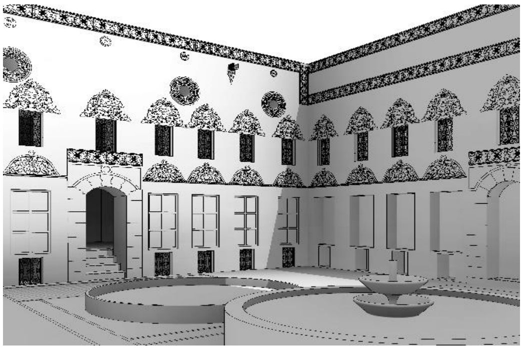

Figure 21. 3d view

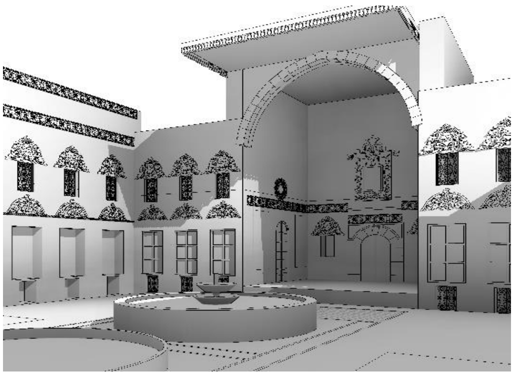

Figure 22. 3d view

- Adjust lighting and material settings to enhance realism.

Figure 23. Rendered 3d view

Figure 24. Rendered 3d view

- **Review and Revision:**

1- Model Review:

- Conduct a thorough review of the model to ensure all details accurately reflect Ajqabash House.

2- Final Adjustments:

- Make final adjustments based on feedback and reviews.

Modeling Ajqabash House and other heritage buildings using Revit and employing Historic Building Information Modeling (HBIM) techniques play a crucial role in preserving cultural heritage and facilitating the restoration of historical structures.as we see before in paragraph 2.3

4.3. Energy Analysis of the House Using Energy Analysis Plug-in:

I conducted an analysis of the sun's movement using the energy analysis plug-in. I prepared the 3D model in Revit as described in the previous section, then set the geographic location and the season for which we wanted to understand the sun's movement.

Figure 25. plug-in icon

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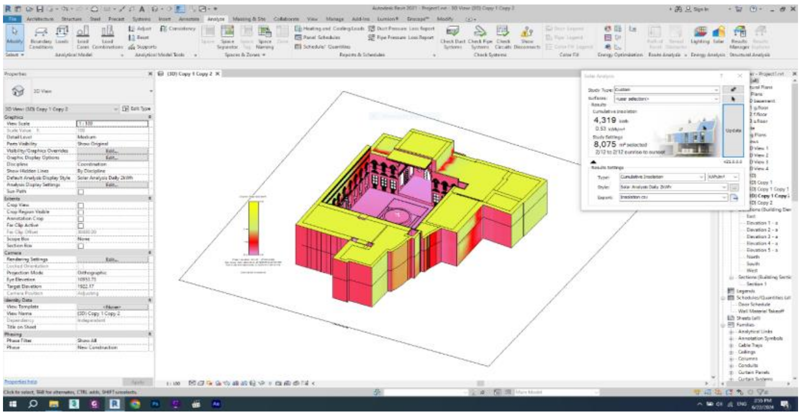

Figure 26. Solar analysis for the house

In August during the summer when temperatures are at their highest:

- The yellow color indicates the highest temperatures, purple is the coldest, and red is in between. In the adjacent image, we notice that the iwan achieves thermal comfort as it is the coldest area during the summer. The façades do not receive direct sunlight, while the roofs, since the building is isolated from the surrounding buildings, and appear to be heavily exposed to sunlight. However, in reality, they are affected by the shadows of the adjacent buildings. Thus, the house, in general, achieves thermal comfort and does not receive direct sunlight in summer due to its inward-facing design.
- When I repeated the analysis in 2010, I found a slight difference indicating that current temperature rates are higher than they were in 2010.

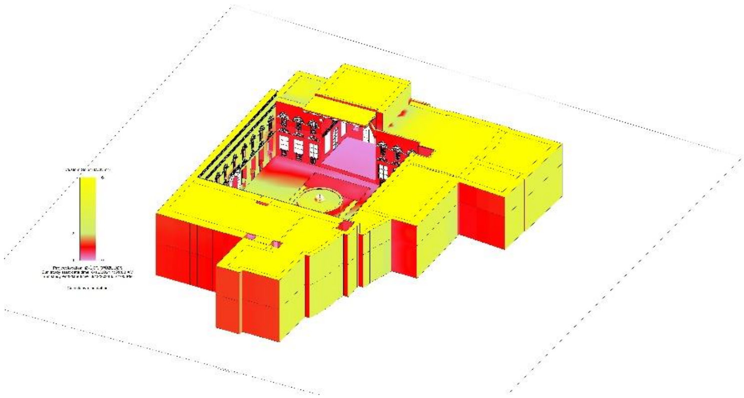

Figure 27. The Iwan in August

During the winter and autumn periods:

- We notice that the reception hall façade is exposed to the sun during winter and autumn, which suggests the idea of using the hall as a winter section. The windows allow the sun to enter the hall, and the walls protect the inhabitants from adverse weather conditions like rain and wind. Due to the thermal insulation and delay properties of the walls, the hall provides thermal comfort during winter. In the summer, due to the airflow.

a. Analysis of the Site, Water, Energy Efficiency, and Building Materials, and Comparison with Green Building Standards:

According to the Syrian Green Building Standard, the most important criteria are energy efficiency and site efficiency. According to section 2.5, the essential requirements for classifying green buildings according to LEED are as follows:

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Energy Efficiency and Indoor Environmental Quality:

- Improving energy performance (orientation)
- Minimum energy performance
- Enhancing energy performance (use of alternative energy)
- Minimum indoor air quality performance
- Increased ventilation
- Use of natural light
- Thermal comfort

Site Efficiency:

- Accessibility for residents, ensuring the site is close to public transport.
- Preserving green spaces and protecting sensitive natural areas.
- Preventing pollution from construction activities.
- Heat island effect
- Parking capacity
- Low-emission transportation
- Increasing open spaces
- Encouraging physical activities and providing paths for walking and cycling.

Compliance of Ajqabash House with These Criteria:

Energy Efficiency and Indoor Environmental Quality:

- **Improving energy performance (orientation):**

The presence of multiple openings in the house directed towards the inner courtyard helps natural light enter the house while protecting from direct sunlight. As seen from the analytical study, the shadows cast by the building around the courtyard prevent direct sunlight from entering the rooms while allowing natural light to penetrate. The courtyard provides an internal shaded area, reducing the heat impact on the building and helping to create a comfortable indoor environment.

- **Minimum energy performance:**

Thermal insulation: The properties of the stone used in the walls and their thickness delay the transfer of heat from outside to inside, contributing to thermal insulation.

Wooden canopy: As noted from the sun analysis, the wooden canopy above the iwan provides additional protection for the iwan area, which is a zone of thermal comfort.

The house achieves the minimum energy performance by focusing on effective thermal insulation, improving natural ventilation, and using the wooden canopy strategically. These architectural elements not only maintain thermal comfort inside the building but also enhance energy efficiency and reduce reliance on artificial cooling and heating systems.

- **Enhancing energy performance and use of alternative energy:**

Although alternative energy was not known historically, the concept of using wind energy positively through the malqaf (windcatcher) to cool and ventilate the house and maintain thermal comfort reduced the need for energy wastage in cooling systems.

- **Indoor air quality:**

The concept of evaporative cooling: The placement of a fountain in the courtyard and a small pond in the basement helped cool the air naturally through evaporation.

The presence of plants in the courtyard improves indoor air quality by producing oxygen and absorbing carbon dioxide and other pollutants.

- **Increased ventilation:**

Malqaf: The malqaf directs wind into the house, providing natural ventilation, renewing indoor air, and reducing heat.

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Inner courtyard: The design of the inner courtyard enhances air movement within the house, providing continuous natural ventilation.

Design of windows in the reception hall: Upper and lower windows allow for natural air renewal.

- **Natural light dependence:**

Open courtyards: The open inner courtyard allows natural light to enter the building, reducing the need for artificial lighting during the day.

Smart window design: Placing windows in strategic locations to allow maximum natural light entry while using traditional shading techniques to prevent glare and excessive heat.

Light colors: Using light colors on walls and ceilings to reflect natural light and distribute it throughout the interior space.

- **Thermal comfort:**

Iwan: As shown in the sun study in the previous section, the iwan provides shaded and cool areas for residents, helping to reduce internal heat.

Inner courtyard: The shaded inner courtyard offers a natural cooling area and serves as a gathering place for residents during high heat periods.

Thick walls and high ceilings: Thick walls retain coolness and warmth as needed, while high ceilings help naturally cool the air through air circulation.

Natural materials: Using building materials such as stone and brick with natural thermal properties helps regulate internal temperatures.

Site Efficiency:

- The dense fabric of the old city provides shade that contributes to energy savings, as shade is one of the most important factors in energy savings, reducing energy consumption by more than 30%, along with aesthetic touches in cities resulting from the difference between sunny and shaded areas due to surface breaks or protrusions.
- **Accessibility:** The house's location is close to public transportation, just a one-minute walk away.
- **Preservation of green spaces and protection of sensitive natural areas:** There are no sensitive natural areas near Ajqabash House. However, like other traditional Arab houses, it features trees in its courtyard, which serve as habitats for birds. The traditional house design generally respects the presence of natural trees, incorporating and harmonizing with the nature of the place where it is built.
- **Pollution prevention from renovation activities:** Efforts are made to minimize pollution during restoration processes.
- **Heat island effect and parking capacity:** The old city's streets, including the Jdeideh area, are paved with stones (rather than asphalt), reducing the heat island effect.
- **Low-emission transportation:** The old city's alleys, which cars cannot enter, primarily rely on bicycles and walking, encouraging physical activities.
- **Increased open spaces:** The old neighborhoods and traditional Arab houses feature inner courtyards, serving as lungs and breathing spaces.

Traditional Elements Contributing to Green Building Requirements:

- The analysis of Ajqabash House shows that traditional architectural elements contribute significantly to meeting green building standards, particularly in energy efficiency and site efficiency. The integration of natural ventilation, use of local materials, strategic design for natural light, and the preservation of green spaces within the architectural design highlight the sustainable practices inherent in traditional buildings.

5. Examples of buildings that used sustainable heritage elements

Within this chapter, I will review global examples of buildings that used Arab heritage elements and achieved the principles of sustainability. I will analyze these examples in terms of location, consideration of the internal

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environment, energy efficiency, in addition to water efficiency and building materials, and the heritage architectural elements that helped achieve these aspects. As a conclusion for this chapter, I will identify some The criteria that can be extracted from these examples for designing modern buildings that contain heritage architectural elements for a more sustainable building that preserves the eastern architectural identity.

Example (1): Al-Dara:

It is the design that won first place in the Future House Competition in the Emirates. And I chose this example because it is a design for a residential house in which the architect Muhammad Al-Mufti created it and gave it the following title: (The House is harnessed) Heritage for a more sustainable future)

Figure 28. Al-Dara

The Block: The form of the block is very simple; it is a rectangular shape with an internal courtyard spanning two stories, inspired by the traditional Arab house.

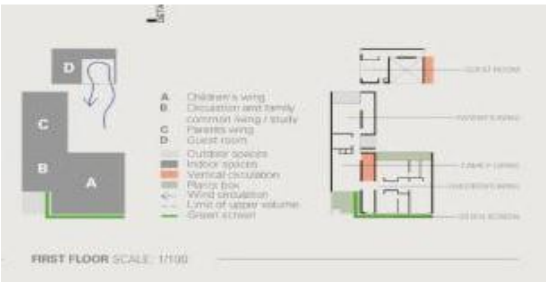

Figure 29. The shape of the building

Figure 30. The shape of the building

Consideration of the Internal Environment and Energy Efficiency: Many sustainable architectural heritage elements that preserve the internal environment were selected. Architect Mufti incorporated the element of the wind catcher (malqaf) to take advantage of natural air by capturing cool air that flows over the house and directing it inside, while expelling hot air. It also helps in removing dust and purifying the air.

The concept of the internal courtyard and the iwan was also used. The central courtyard acts as a thermal regulator, benefiting from the significant temperature differences between night and day and creating varying pressure zones between the shaded narrow rooms and the open central courtyard. At the beginning of the day, the central courtyard still retains the cool air it acquired at night, and it is entirely or partially shaded, providing a comfortable area for the residents. As the sun's angle increases and temperatures rise during the day, the central courtyard becomes like a thermal chimney, while the shaded rooms retain their coolness, creating high-pressure areas. This causes the cool air to move through the openings in the walls of the residence. In the evening and nighttime, the cool air gradually descends and accumulates in the central courtyard, a process known as Night Flushing. A water surface was used in the courtyard to cool the air and freshen the atmosphere.

Additionally, the concept of mashrabiyas was used as external screens to provide privacy and control the amount of heat and light entering the building from the outside.

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Figure 31. The plans of the villa

Figure 32. The plans of the villa

Water Efficiency: The designer relied on the idea of the fountain used in the traditional Arab house by placing a water surface in the middle of the internal courtyard in front of the iwan to freshen the air. The designer also applied the principle of water efficiency by collecting and recycling water to use it for watering plants

Building Materials: The designer used concrete for construction and also utilized local materials such as palm fronds, which are characteristic of the Gulf region, to cover the external openings.

Figure 33. Elements of sustainable living

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Example (2): Lucidity Villa

Figure 34. The design idea

Figure 35. The external elevation

The villa, designed by Syrian architect Faiz Jazmati, aims to achieve privacy, which is one of the key factors for a comfortable residence. The solution was to return to the concept of traditional Arab houses with internal courtyards.

Location: The villa is located in Dubai, UAE, on a plot surrounded by several neighboring lots. The challenge of this site was how to achieve privacy without compromising the openness of the house.

The block: The ground floor is U-shaped, open from the north side, as the favorable winds in the UAE are the northern (cool) winds. The first floor is entirely solid to reduce the northern opening on the ground floor, creating what is known as a wind tunnel to facilitate the entry of the cool northern winds. A water feature was placed inside this courtyard to cool the winds and create what is known as passive cooling.

Figure 36. The idea of lucidity

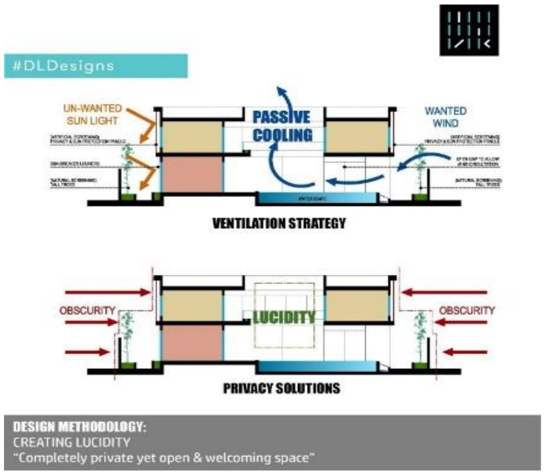

Figure 37. Ventilation and privacy solutions

Consideration of the Internal Environment and Energy Efficiency: From the above explanation, we notice that the architect chose the concept of passive cooling to create thermal comfort inside the villa by using the internal courtyard with a water feature. For the facades, sun breakers were used to reduce the entry of unwanted sunlight, and a canopy of tall trees was placed to improve the climate inside the villa.

Building Materials: The designer used fiberglass panels on the external facades to provide a sense of privacy and mystery from the outside while allowing light to enter the residence. The internal elements are open to the internal courtyard with clear glass, ensuring privacy and transparency towards the interior.

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Figure 38. Inner elevation

Figure 39. External elevation

6. Conclusions and Recommendations

- **Conclusions:**

Effectiveness of BIM Techniques in Modeling Heritage Buildings: The use of BIM and Revit technologies in modeling and analyzing the heritage building of Ajqabash has proven effective in studying energy efficiency, site suitability, and indoor environment, enhancing the understanding and application of heritage architectural elements in modern designs.

Compatibility of Ajqabash with Green Building Standards: Analyses have shown that Ajqabash complies with green building standards concerning energy efficiency, site suitability, water use efficiency, and indoor environment quality. Which lead us to the fact that the green architecture is not a new concept, and our traditional buildings have achieved sustainability long time ago. And we must go back to our history to build a better sustainable future using the traditional element in modern ways

Importance of Sustainable Heritage Architectural Elements: Global models of sustainable buildings that integrate heritage architectural elements such as internal courtyards, mashrabiyas, solar chimneys, water features, and sun breakers emphasize the importance of these elements in achieving building sustainability.

- **Recommendations:**

Based on the above conclusions, the following recommendations can be proposed for the development of modern housing

1. **Enhancing Architectural Identity through Reviving Heritage Elements:** Integrate sustainable heritage architectural elements into modern building designs, such as internal courtyards, mashrabiyas, and solar chimneys, to enhance architectural identity and preserve heritage authenticity.
2. **Consideration for the Environment and Local Climate:** Designers should consider local climate conditions in their cities when designing new buildings, employing techniques like natural ventilation and using sustainable local materials.
3. **Utilization of BIM Techniques in Design and Analysis:** Encourage the use of BIM techniques throughout the design and construction phases for accurate modeling and analysis of energy efficiency, site suitability, and indoor environment, contributing to sustainable and high-performance buildings.
4. **Learning from Successful Global Models:** Study and analyze successful global models that incorporate sustainable heritage architectural elements, applying lessons learned to local projects to achieve maximum sustainability.
5. **Development of Local Sustainable Design Standards:** Develop local design standards that blend architectural heritage with modern technology to create modern, sustainable buildings with authentic identity that meet residents' needs and enhance quality of life.

- **Detailed Design Standards:**

1. **Innovative Use of Mashrabiyas:**

Advanced Design: Integrate modern materials like double-glazed glass and recycled metal in mashrabiyas to achieve a blend of traditional aesthetics and environmental efficiency.

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Smart Controls: Equip mashrabiyas with smart control devices to regulate natural ventilation and lighting according to varying climatic conditions, enhancing energy efficiency and reducing electricity consumption.

2. Design of Internal Courtyards in Residential Villas and Building Clusters:

Residential Villas: Design internal courtyards as central green spaces, utilizing local plants for natural cooling and improved air quality. Consider using water features as swimming pools to enhance indoor climate and reduce temperatures.

Building Clusters: Design residential complexes around a central communal courtyard, promoting social bonds and providing shared green spaces that mitigate urban heat island effects.

3. Use of Sustainable Local Materials:

Carbon Emission Reduction: Encourage the use of local building materials such as stone and wood to reduce carbon emissions from transportation and support the local economy.

Material Recycling: Use recycled materials in construction, especially after the significant destruction the city has experienced, to reduce waste and promote environmental sustainability.

4. Development of Malqaf for Natural Ventilation:

Innovative Malqaf Design: Develop traditional chimneys to include modern technologies like solar panels and smart ventilation devices to improve air flow and provide natural ventilation. This can reduce the need for air conditioning and enhance indoor air quality.

Integration with Overall Design: Incorporate chimneys into building designs as part of the building's environmental system, enhancing energy efficiency and thermal comfort for residents.

By implementing these detailed design standards, a balance can be achieved between innovation, modern technology, and heritage authenticity, leading to sustainable, environmentally integrated, and culturally rich modern buildings.

Note: all the images, drawings, and diagrams are exclusive to the researcher, and they part of a thesis titled “Heritage Sustainable Architectural Elements and their reuse in modern residential buildings utilizing BIM technology”, prepared for the Master`s degree in the BIMM program at the SVU.

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