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Exploring the principles of sustainability in the traditional dwellings of the Old City of Mosul

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Abstract

The concept of sustainability has recently as a very important issue in different in aspects of society. Which means the optimal and effective exploitation of available resources and capabilities across various environmental, urban, social, and other domains to preserve these resources and ensure their continuity for future generations. The importance of this research lies in focusing the principles of environmental sustainability in traditional local architecture. Traditional residential buildings in the Old City of Mosul, Iraq, represent a distinctive model of local architecture, characterized by their suitability for environmental and climatic conditions and their use of local materials. They also include design features that increase the thermal insulation and natural ventilation, such as open interior spaces (courtyard) and other local architectural elements. The research aims to identify the local architectural elements of the Mosulin elements houses and their role in achieving various sustainability principles. The research concluded that the local building methods in Mosul can riches enhance environmental sustainability in current construction projects, especially with climate change. The research will contribute to a re-evaluation of the importance of traditional architecture in achieving environmental sustainability goals.

Keywords: Sustainability, Old Mosul, Traditional dwellings, Architectural design, Passive energy

1. Introduction

The Old City of Mosul is considered the origin of the modern city of Mosul, as it contains many important historical monuments. It is also one of the most important heritage centers that is still inhabited and contains a treasure of Islamic architectural heritage. The city includes many palaces, mosques, churches, inns, and baths, in addition to various urban spaces such as squares, markets, and alleys [1], [2]. Despite being severely affected by conflicts in recent years, it still represents a reflection of traditional social life on the one hand and traditional architecture on the other, due to its unique urban and architectural character. However, in recent years, this culturally and socially rich city has faced many challenges, including the destruction of historical monuments such as the Al-Hadba Minaret and the Al-Tahera Church, damage caused by conflicts, and the destruction of a large proportion of the Old City of Mosul's housing, which represents an architectural treasure in terms of authenticity, occupancy, and diversity, as it includes elements of sustainability, whether environmentally,

economically, socially, or contextually. The collapse of a large number of traditional houses in Old Mosul, or illegal modifications, has led to the loss of its unique architectural elements. Especially since little has been written, documented, or published about the architectural characteristics and sustainability aspects of these units, leaving a gap of undiscovered architectural intellectual treasure. It is therefore of utmost importance to develop plans for the repair and rehabilitation of these houses to preserve the identity of Old Mosul [3]. The concept of sustainability is based on creating a balance between the environment, the economy, and society to preserve wealth for future generations. In recent years, there has been a growing interest in sustainable architecture which goal to achieve and keep natural instead of controlling it. The construction of traditional houses relied on the use of natural materials, focusing principles of stability and durability while taking into account the impact of natural factors such as light and wind [4]. This study will deal the sustainability principles which construct in the local houses in Old Mosul, with a focus on the elements of these houses that contribute to their inhabitants' thermal comfort.

2. Background and significance

Old Mosul, located on the north of Iraq west bank of the River Tigris, and it has of very importance in the context of the history and architecture of Iraq [5]. It famous for its antiquity (Al-sooq) that are constantly, as well as the unique topology of the city [6]. It has been vulnerable to dominance of different civilizations, because of this location, include the Assyrian, Babylonian, and, the Islamic civilization. Each one of these has put a unique stamp on the evolution and rich heritage of the city [7], [8]. The unique architectural style is portrayed in the old houses of the old city of Mosul, have huge significance but are increasingly endangered due to the lake of proper conservation works [9], [10]. The old city has faced intricate that have had negative effects on the historically important old houses. Among the most significant and influential take- over terrorist gangs of ISIS of the city. In addition to the ill-considered methods of reconstruction after the destruction of the city, which has endangered the architectural heritage inherent in Mosul’s traditional dwellings [11]. In response to these threats, the study aims to identify and explore the principles of sustainability in these dwellings. To this end, the research collected architectural models representing a typical Mosul dwelling, including those that remained intact and those that were rebuilt after the destruction caused by the war. This case study was subsequently analyzed to understand and explore the principles of sustainability in these dwellings within the climatic, social, environmental, and ecological dimensions.

3. Research objectives

If contemporary architectural designs rely mainly on electrical energy and mechanical systems to provide thermal comfort for building occupants, traditional houses in the Old City of Mosul have reflected the principles of sustainable design by using passive techniques to enhance internal thermal comfort [12]. The current research focuses on analyzing a selected group of traditional houses in the old city of Mosul to achieve the following objectives:

- Documenting the architectural characteristics related to the different sustainability principles of traditional houses.
- Highlighting the importance of sustainability principles in traditional architecture in achieving environmental, social, and economic sustainability in contemporary architectural design.
- Identifying the architectural elements of traditional Mosul houses and their role in achieving the different sustainability principles.

4. Sustainability in architecture and traditional architecture

Sustainable architecture focuses on designing and building in a way that minimizes the negative impact on the environment by increasing the efficiency of a building’s performance. In addition to reducing its negative impact on the surrounding areas by increasing energy and environmental efficiency [13]. Building in this way allows the environment and resources to be preserved together in a long-term balance. Sustainable construction is un

umbrella term for several different approaches that aim to reduce the negative impact of construction on the ecosystem, which include energy consumption, waste management, and the controlling greenhouse gas emissions and their environmental impacts. It is important of this topic has been rising in view of the increased challenges with climate change and natural resource lack. As there is a growing need for infrastructure that supports humanity develop, and particularly in the wake of an expanding urban population. So, it necessary informed by sustainable architectural principles that are increasingly gaining importance [14].

Which is consider fundamental of that, also the lake of resources nature make that they use natural resources carefully as a means of keeping harmony between human beings and nature to faced big challenges, as poor weather or lack of food. Sustainability appeared to be an instinctual mindset ingrained in these societies [15]. Our ancestors interacted with their environment not randomly and instinctively, but based on gradual stages of experiential learning of "trial and error", creative thinking, and alert reasoning. Many recent studies also point out how important these methods are, as well as how they should be applied. Sustainable design elements are incorporated in conventional architectural methods. They perform satisfactory in local climate, and they use materials which are easily accessible, simple approaches, and effective. As a results, there is no clash between these architectural construction and nature, since they use natural resources without interfacing with or controlling them. Furthermore, green architecture expert Brian Edwards points out that social sustainability is linked to environmental requirements, and that traditional architecture is a distinctive feature of this, saying "Traditional architecture has integrated the principles of social sustainability with environmental requirements" [15] ,to produce a sustainable architecture that fits in naturally [16]. Many sustainability researchers have focused on traditional architecture, which has focused the ecological role of the central courtyard and natural materials such as mud and straw. Its widespread acceptance by both environmental sustainability and green architecture professionals indicates the importance of studying traditional architecture to gain new insights into future building practices.

5. Literature review

5.1. Climatic measures in the traditional architecture of Mosul

Abdul Karim and Al-Nasiri's study concluded that many studies have focused on the climate adaptation of traditional dwellings in Mosul. It was concluded that the spatial configuration of these dwellings and the presence of open interior spaces significantly affect thermal comfort. These designs create microclimates that cool the air during the summer months and keep it warm in the colder season. These traditional solutions are applicable today-especially in light of climate change. The use of local materials also moderates the internal temperature, as the study found that using locally sourced limestone in Old Mosul not only reduces waste generated by construction but also provides natural thermal insulation, reducing heat entering homes during the day and helping to maintain comfortable internal conditions without intervention on energy-consuming mechanical systems [17].

5.2. Modern interpretations and applications of traditional sustainability

Al-Kubaisi and Qasim [10] pointed out in their study to benefit from past experiences to solve environmental problems, as they called on architects and urban planners to integrate traditional design principles found in the buildings of old Mosul into modern sustainable construction practices. Their study focused on the reconsidering passive design strategies, especially in courtyard housing, and to using local materials in developing new urban housing projects. In a comparative analysis of traditional and modern housing, the study found that most modern buildings consume a lot of electricity from air conditioning operations. The researchers confirmed that adapting traditional designs in Mosul to modern needs can reduce energy consumption [18].

5.3. Challenges and opportunities

The study concluded that there is a missing link between traditional and modern architectural practice. Despite the great positives of traditional building methods, especially concerning environmental sustainability, reusing

these methods in modern contexts is not without challenges. Adapting traditional materials and designs characteristics to fit contemporary building standards and codes can be complex. In addition, despite the growing interest in local architecture. the research pointed to the problem of lake of skill labor in traditional techniques and the high costs of some sustainable materials, all of which may hinder the widespread adoption of these methods. However, the study pointed to the importance of the role of government incentives, community engagement, and further research into material innovations that can allow traditional architectural methods to flourish again, while the study identifies that digital tools such as geographic information systems and modern construction technologies, such as 3D printing, may be the missing link between traditional and modern architectural practice [19].

5.4. The principles of sustainability in traditional architecture

Most previous studies have highlighted the basic elements of sustainability in traditional architecture, as shown in Figure 1. The features of sustainability in architecture are deeply rooted in traditional construction methods that have evolved in response to the climatic conditions and cultural environment of the site, and according to the characteristics of the site it occupies [20], [21].

Figure 1. The principles of sustainability in traditional architecture (P)

5.4.1. Environmental sustainability

Use of local and sustainable materials (P.1.1): The choice of building materials plays a significant role in achieving sustainability in construction. How these materials are sourced and selected significantly affects energy consumption, air pollution arising from their manufacture, and thus the overall environmental impact [22]. Builders relied on local, natural, non-toxic materials such as limestone, clay, bricks, and gypsum, which were readily available from nearby quarries and mud flats. The region used hardwood and semi-hardwood from trees and palm trunks, which not only served as building materials but also provided shade and cooling benefits. Natural soil was also utilized in traditional roofing methods through the use of stone, brick, and gypsum, in the vaulted ceilings of many houses, mosques, and churches built during the same period. It should be noted that all the materials used are capable of decomposing naturally once they are no longer in use, to reduce potential environmental impact. The preservation of the Old City of Mosul is not only imperative from perspective of its rich architectural, but it is also form the perspective of sustainable building designs, which could act as a template for other places facing similar challenges.

Climate-responsive design (P.1.2, P.1.3): The regions with a dry, hot climate in summer, such as the study area, are characterized by their traditional use of passive cooling and heating to ensure thermal comfort in summer and winter. In traditional architecture, passive techniques were widely used during the design and construction stages of houses, [23] to adapt to the hot and dry climate. Courtyards are an essential feature of traditional

houses, as they work to adopt natural ventilation and passive cooling. Thick walls, narrow windows, low-rise housing, narrow streets, and ventilation openings are examples of passive strategies used in traditional housing [24]. The most prominent passive cooling techniques and strategies that have been optimally exploited in traditional housing can be categorized into four main groups: microclimate and site design strategies, building envelope design strategies, natural ventilation design strategies, building resources and materials. Traditional houses were oriented to receive prevailing winds and limit exposure to sunlight during the hot summer months. Thick walls were built to provide natural insulation, keeping the interior cool during the day and a warm at night [21].

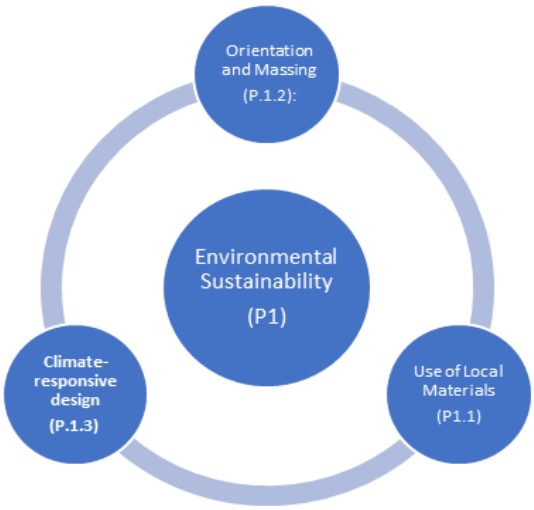

Figure 2. Environmental sustainability (P.1) source researcher

5.4.2. Social sustainability (P.2)

Urban Design of Fabric (P.2.1): The local urban design of Mosul's neighborhoods (Al-Mahala) reflects social sustainability. Narrow alleys and increasing the interaction social community [25].

Multi-generational living (P.2.2): The traditional houses can be expanded and adapted to grow in family size and accommodate families at different stages of their lives under one roof, providing a community-focused lifestyle.

Preservation of cultural heritage (P.2.3): Keeping of the cultural identity heritage the local traditional urban architectural reflects the identity and culture of the city, riches its connection to the place [24].

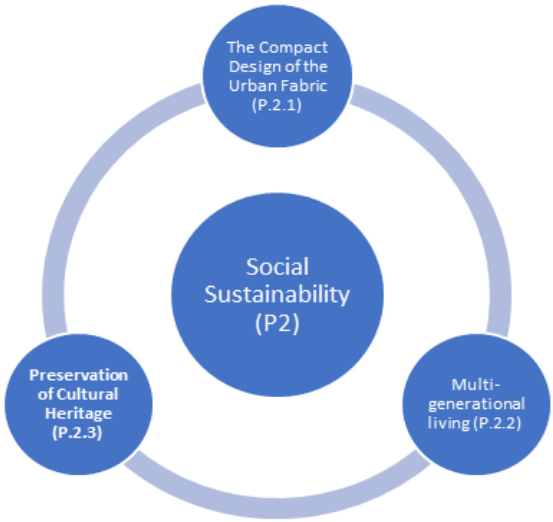

Figure 3. Social sustainability (P.2) source researcher

5.4.3. Economic sustainability (P.3)

Affordable construction (P.3.1): The availability of local materials in build made traditional buildings more economical.

Durability and ease of maintenance (P.3.2): Local houses were built to remind for long time, so it is not need maintenance or reconstruction [25] .
Energy efficiency (P.3.3): Natural ventilation, lighting and cooling which are used in local houses reduced the cost of energy.

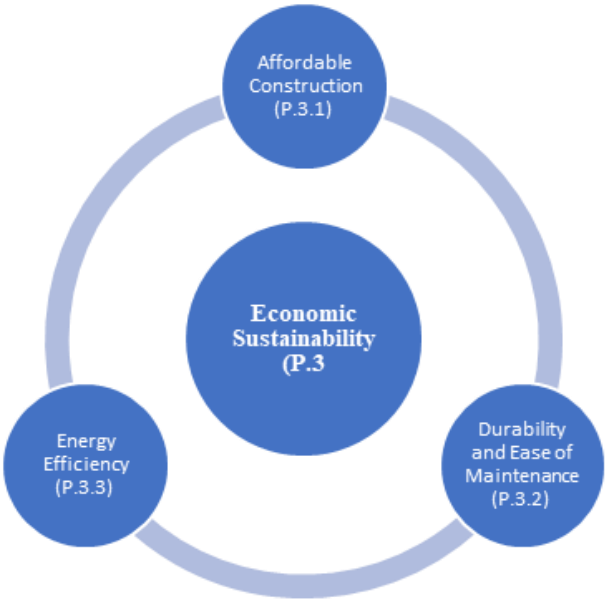

Figure 4. Economic sustainability (P.3) source researcher

5.4.4. Sustainability of water resources (P.4)

Rainwater harvesting (P.4.1): Traditional buildings have the flat roofs to collect rainwater, then directed it to courtyards or underground cisterns for reuse. This method of rainwater harvesting reduces water waste [26].
Efficient use of water (P.4.2): Water conservation was a way of the Old City, with traditional techniques focusing on managing water resources efficiently through reuse and storage.

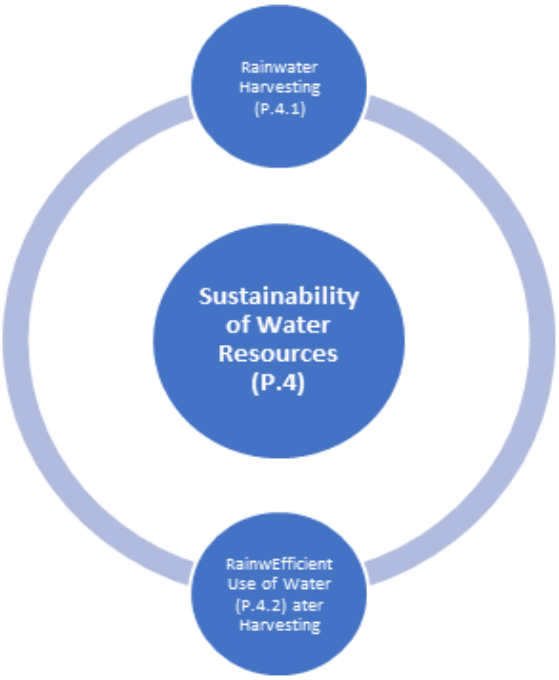

Figure 5. Rainwater harvesting (P.4.1) source researcher

In the traditional Mosul architecture, sustainability was not a separate concept but an integral part of the design, reflecting a deep understanding of the environmental, social, and economic needs of the community [27].

5.5. The mechanisms to achieve sustainability in traditional architecture

Traditional architecture, which has evolved over a long period of time as a result of trial and error by users, is supposed to provide solutions to contemporary sustainability issues. This architecture has survived centuries of changing climatic conditions, making its response effective to the local climate, in terms of form, materials, and construction technology [28]. Sustainability is a three-pillar approach, social, economic, and environmental, where all three pillars must be interconnected. According to Irani, buildings should be designed through a balance between these three dimensions [29]. To achieve better performance in one or more aspects, this balance can be exceeded, for a certain period, which requires specific architectural intervention. Environmental sustainability is related to the integration of environmental criteria into design. Therefore, the research will deal with the mechanisms of achieving the environmental and social dimensions of sustainability in architectural design in the context of passive energy mechanisms and social interaction. Therefore, the general guidelines and methods for achieving sustainability in traditional architecture can be as follows.

Planning and location of the site: In traditional architecture, the site is an essential part of the entire urban structure of the city. From the building blocks to the organic roads and open squares, the urban structure of the traditional city is naturally woven together [30]. Mechanism: An integrated (organic) fabric. The building blocks are semi-deaf from the outside, and the alleys are narrow to protect from foreign hazards or harsh environments, and the blocks extend over the alleys (Qantara) to provide shade on those thick walls [30].

Use of local materials: Most traditional buildings use materials available in the region, which reduces transportation costs and causes less damage to the ecosystem. Mechanism: Promoting the use of local and recycled building materials to reduce energy and carbon footprint [31].

Climate adaptation principle: Traditional buildings are designed to adapt to the prevailing climate, using passive design techniques to control heat, light, and ventilation [32]. Mechanism: The main passive design principles are natural ventilation, thermal mass, and orientation, which minimize the use of artificial heating and cooling systems. The technique used here involves the incorporation of basements, central courtyards, as well as windcatchers, which play acritical role in the process of harnessing the wind, while using pressure differences between the indoor and outdoor factors. Moreover, the use of water features such as fountains, also serves the role of raising the humidity surrounding the environment while cooling it as well [33].

Architectural features such as heavy thick walls, and various projections characteristic designs residential architecture that have been specifically designed to promote energy efficiency. The basic aim is not provided maximum shading on the rooftop. Mechanism: In traditional architecture the roofing system includes domed and vaulted structures erected over arches, whereas the external envelope consists of robust walls made from ecologically sustainable materials such as a natural stones, plaster, and brick, each with its own characteristics. The use of these materials in modern architecture is fundamental as they improve heat transfer resistance as well as reduce the effect of external climate fluctuations inside the building structure [30].

Cultural and social plural formula: Traditional architecture reflects the cultural and social practices of the community, and creates spaces that enhance social relations and social interaction [34]. Mechanism: Creating social interaction spaces for maintenance of traditions such as culture values and requirements for privacy through the use of the inner courtyard and the Iwan [35].

The principle of biodiversity in natural furnishing elements such as water ponds and green spaces, courtyards and gardens, which are an integral part of local architecture, not only enhances biodiversity but also provides natural cooling mechanisms. Mechanism: Green spaces, such as inner courtyards and water bodies, improve air quality and mitigate the effects of heat [36].

The principle of waste reduction: Traditional buildings produce little waste, and their designs promote repair and reuse. Mechanism: Use recyclable materials, such as plaster and stone [37].

6. Research statement

The traditional dwellings in the Old City of Mosul represent a rich cultural and architectural heritage, and most studies have indicated their harmony with the local environment and the principles of architectural sustainability. However, these principles have not been explored in all their details, and they are being ignored and lost, especially in the process of rebuilding the buildings of the Old City of Mosul. Therefore, the problem of the research lies in the failure to confine the principles of sustainability in detail to the buildings of old Mosul. With need to explore and document the principles of sustainability in the traditional dwellings of the old city of Mosul, especially climate adaptation, the use of local materials in construction processes, and positives social integration, for reuse in modern architectural design.

7. Research materials and methods

7.1. Traditional houses in Old Mosul

The Old City of Mosul is famous for its traditional heritage buildings. Its rich architectural heritage, dating back to the 12th and 13th centuries AD, periods it represents a significant cultural center in the Middle East. It comprises a rich heritage of mosques, schools, of Islamic thought, churches, historic residential, and commercial buildings among other architectural features. Most of these buildings were built from (stone, mud, and wood) [38], [3].

The traditional houses of Old city of Mosul symbolize a rich from local Islamic architecture styles from the very early Islamic period. These architectural styles are culminated from local architecture elements with defined environmental, social and cultural parameters and factors. These houses of Old Mosul are recognized by architectural styles, decorations, and local materials. These buildings consist of two to three floors, are built of local stone and plaster (Zakur), with wide variety of social and cultural styles, Thet basically composed series of rooms, a central courtyard, and central halls with vaulted ceiling [38]. There are a wide variety of decoration with architectural design parameters like cornices and flowers among others, However, a significant number of houses from old city if Mosul have experienced damage have been totally unfortunate that hundreds of these heritage buildings have been damaged or destroyed due to conflicts, and influence of radical ideologies over the past few decades [38].

7.2. Architectural styles and features

The dwellings in the Old City of Mosul are classified into two architectural styles: Mosul. If the concept of "host" is common in the first style, with a central courtyard, with rooms arranged around a courtyard, and it has arched ceilings and large windows decorated with "AL-Mashrabiya" and wooden balconies. The decorations usually adorn the façade. This style also symbolizes the social status of the owner. In contrast, the second style is smaller and is characterized by a simple vestibule and decorations, and does not contain a balcony [3].

The unique architectural characteristics of traditional houses in Mosul can be divided into two categories: external and internal. The external features are the façade, roof, balcony, and windows, while the internal features are the different rooms inside the house. Traditional houses in Mosul are generally built from local materials such as stone, plaster, brick, and wood. The use of these materials gives the city its character. Walls, arches, and columns are often made of stone, which was originally obtained from the nearby hills and mountains. In addition, gypsum is used in specialized craftsmen's engravings. Wood was also used in the past to build roofs and support projections and door and window openings, but its limited availability prompted builders to use other materials for more recent constructions [39].

7.3. Materials (selection of case studies)

Several criteria were utilized to select the buildings examined in this research, as outlined below:

- Location: The chosen projects are situated in the heart of Old Mosul.
- Social Significance: The buildings selected exemplify the typical Mosul house, being relatively spacious dwellings that incorporate many of the distinctive features of a Mosul house, such as the open courtyard, Iwan, Badkir, Basement, Shanshoowls, and other traditional architectural elements.

- Functional Sustainability: Some of these structures, like the selected Al-Tutunji House, have experienced significant changes in their function and now serve public purposes, accommodating a diverse array of people and demonstrating their efficient use for various functions.
- Heritage Status: The chosen buildings are designated as heritage buildings recognized by the Mosul Heritage Department as national heritage.
- Availability of Documentation: Adequate documentation was available for the selected cases.
- These criteria resulted in the selection of four projects.

7.3.1. Beit (House) Abduni

Beit Abduni builted in 1710. It is found in the Al-Mayassa district of Mosul. This architectural masterpiece A seen in Figure 6, illustrates traditional courtyard reflecting the cultural richness of the city in terms wood and plasterwork, craftsmanship[40].

Figure 6. Abduni house

7.3.2. Beit (House) Al-Jalili

Beit Amin Bek Al-Jalili was built in 1747. Is located in the Imam Awn Al-Din neighborhood of Mosul (see Figure 7). Beit Amin Bek Al-JaliliIt represents traditional Mosuli architecture style, where there is an emphasis on a courtyard design as well as a design that includes extensive use stone and wood [40].

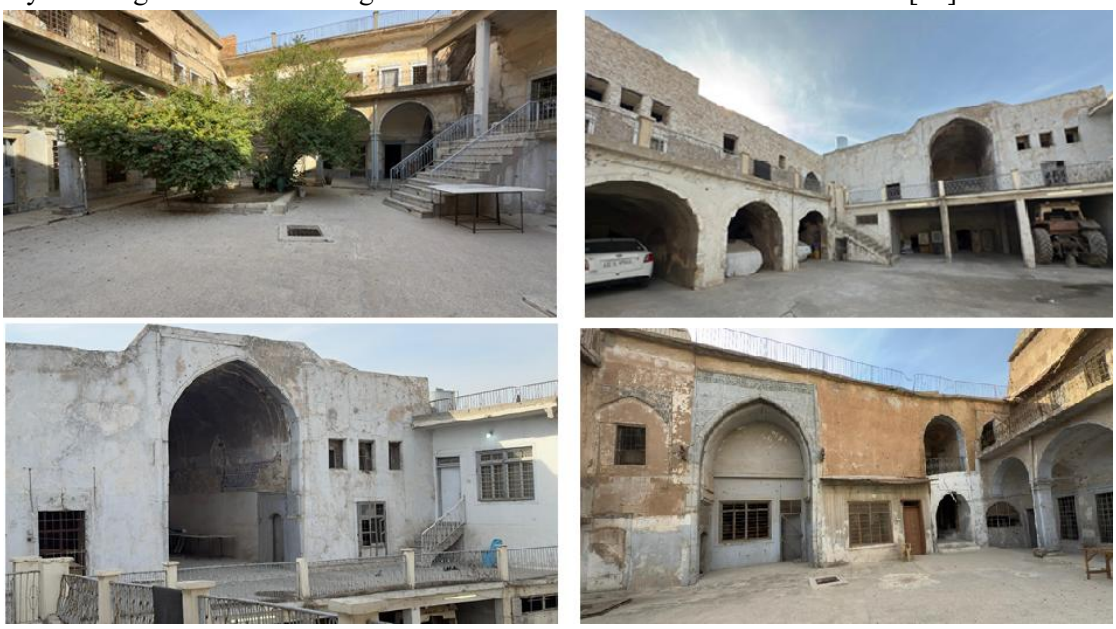

Figure 7. AL Jalili house

7.3.3. Beit (House) Al-Tutunji

Beit Al-Tutunji erected in 1815, is a historic house standing at the Al-Souq Al-Sagheer, which is a neighborhood of Mosul. This structure exhibits the Mosuli architecture style featuring the central courtyard as intricated by t Figure 7[40].

Figure 8. Al-Tutunji house

7.3.4. Beit (House) Ziada

Beit Ziada was built in 1870 (Figure 9). It is located in Mosul's Bab Al-Baidh Al-Gharbi . This house represents traditional Mosul architecture with a central courtyard, it represents the symbolizing the city's rich heritage [40].

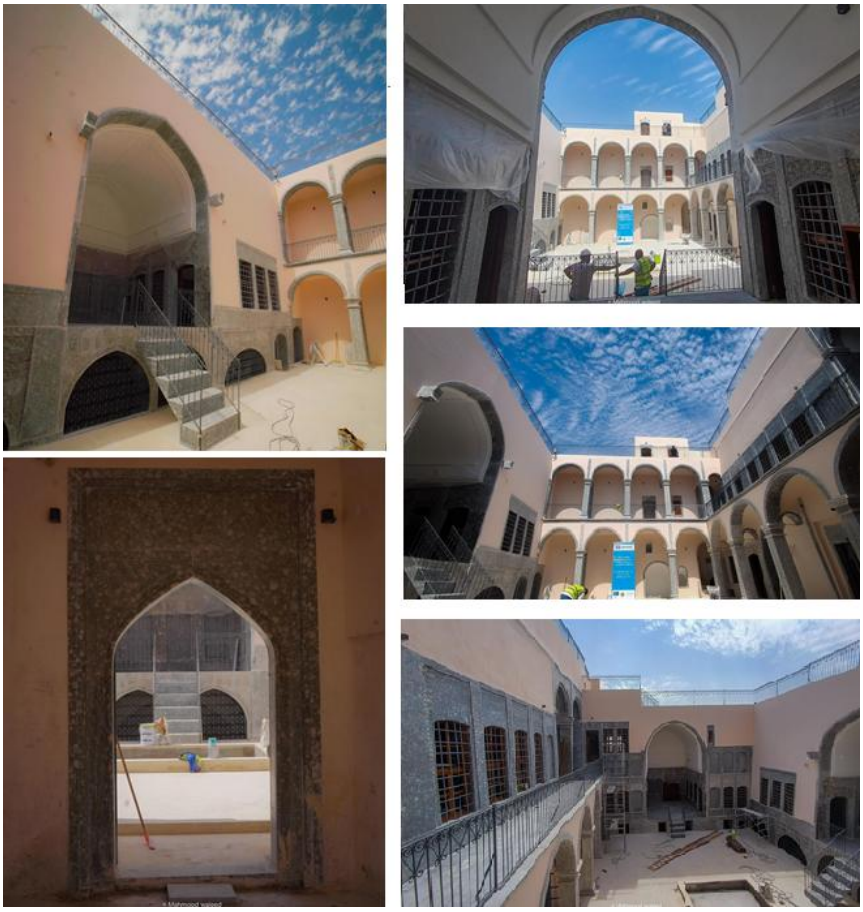

Figure 9. Ziada house

7.4. Methods

7.4.1. The principles of sustainability

Table 1 provides detailed classifications across three columns: principles, mechanisms, and traditional examples, illustrating how these concepts were historically applied in traditional architecture.

Table 1. Principles, mechanisms, and traditional examples

No.	Principle	Mechanism	Traditional Examples
1	Planning and Dealing with the Site	X1 – Integrated (organic) urban fabric X2a – Central courtyard for environmental, aesthetic, and social needs (privacy, inward orientation, protection from external elements)	- Traditional Middle Eastern and Mediterranean homes with central courtyards - Organic layout of ancient cities - Narrow streets (organic pattern)
2	Use of Local Materials	X3 – Use local, renewable, and recycled materials to minimize transportation costs and reduce carbon footprint	- Mudbrick houses - Stone and plaster houses
3	Climate Adaptation	X4 – Use passive design strategies (natural ventilation, thermal mass, orientation) X5 – Fountains, and basements to cool spaces naturally	- Wind catchers (*malqaf*) - Courtyards - Fountains and basements
4	Energy Efficiency (Passive Energy Design)	X6 – Thick walls, hollow domes, and arches to increase shading and insulation X4, X5, X6- Multiple building materials to improve thermal resistance (stone, brick, plaster)	- Dome structures in Islamic architecture (e.g., mosques) - Thick walls of rural Moroccan homes for insulation
5	Cultural and Social Integration	X2b – Design spaces that promote social interaction and privacy (e.g., inner courtyards, iwans) X1 – Foster cultural values through building orientation and layout	- Inner courtyards and diwans
6	Waste Reduction	X3 – Use recyclable materials such as plaster and stone; Design for easy repair and reuse	- Reuse of stone from ancient ruins in medieval European structures - Mudbrick structures are repaired annually in Mali

7.4.2. Analysis of collected data

The following discussion, based on the principles and tools for sustainability that were described in table 1 (X1-X6), illustrates how these principles and tools are work in traditional houses through the proposed model of study. The Figures explain a particular aspect of these principles and tools, starting from site design and through to climatic effect and, finally, to residents' interaction, with methods of their incorporation in the architectural context of old Mosul. In particular. (Figures 10-13).

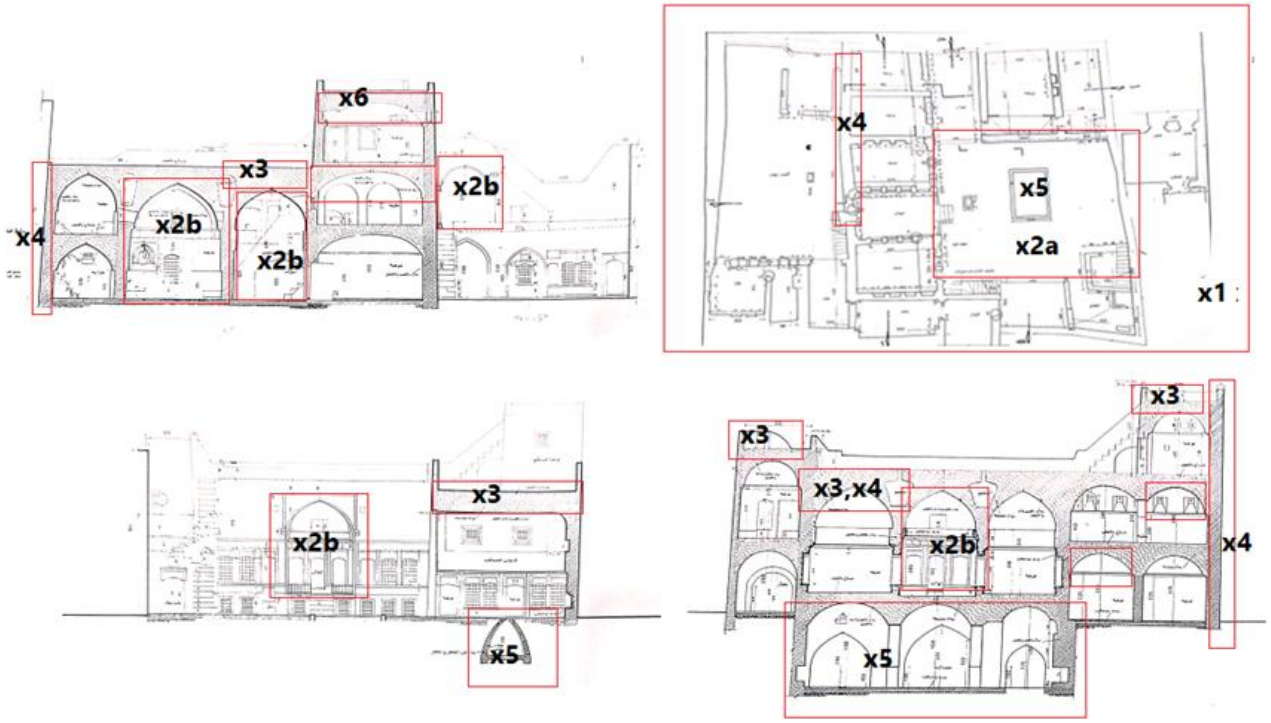

Figure 10. Principles of sustainability, Beit (House) Abduni

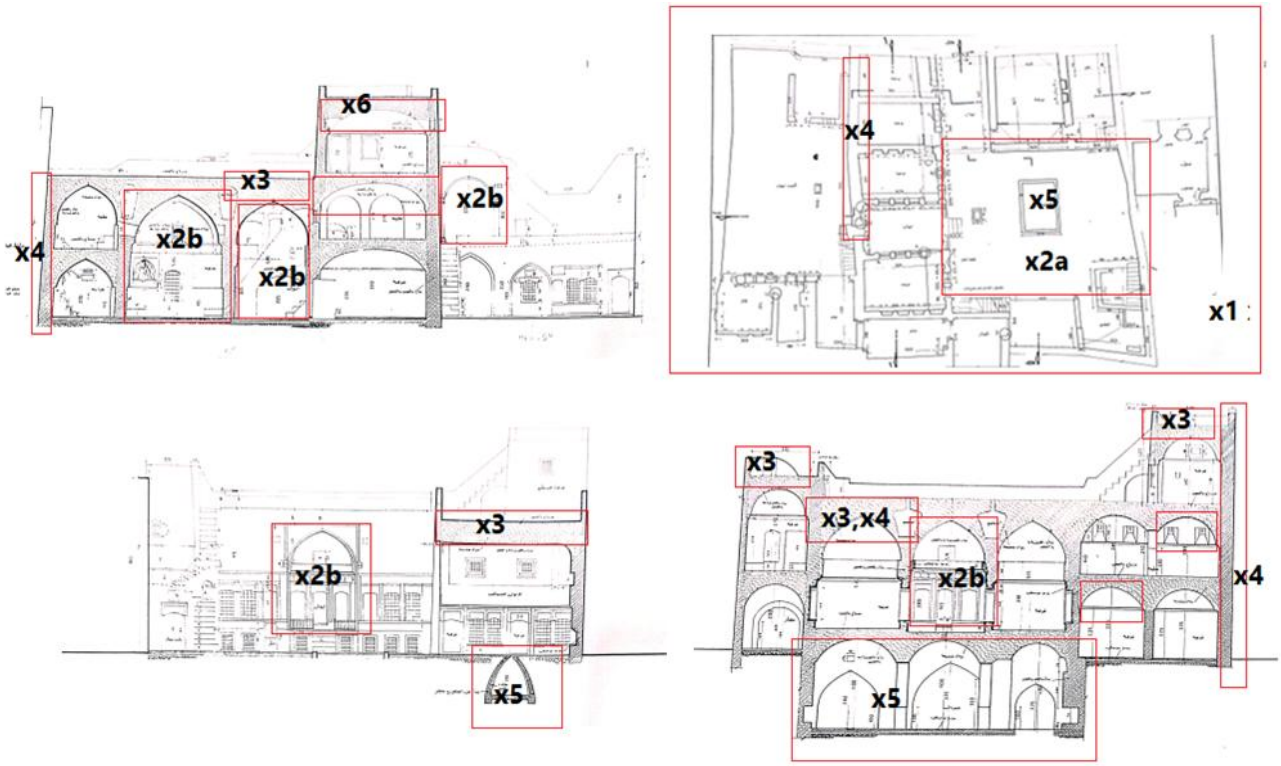

Figure 11. Principles of sustainability, Beit (House) AL Jalili

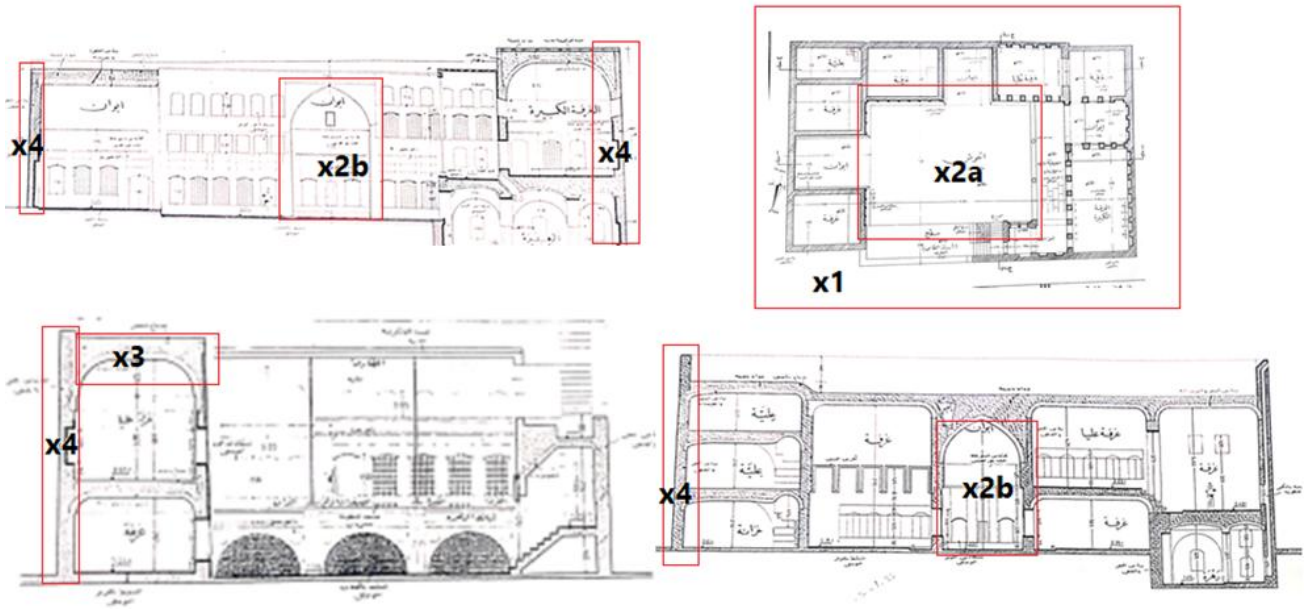

Figure 12. Principles of sustainability, Beit (House) Al-Tutunji

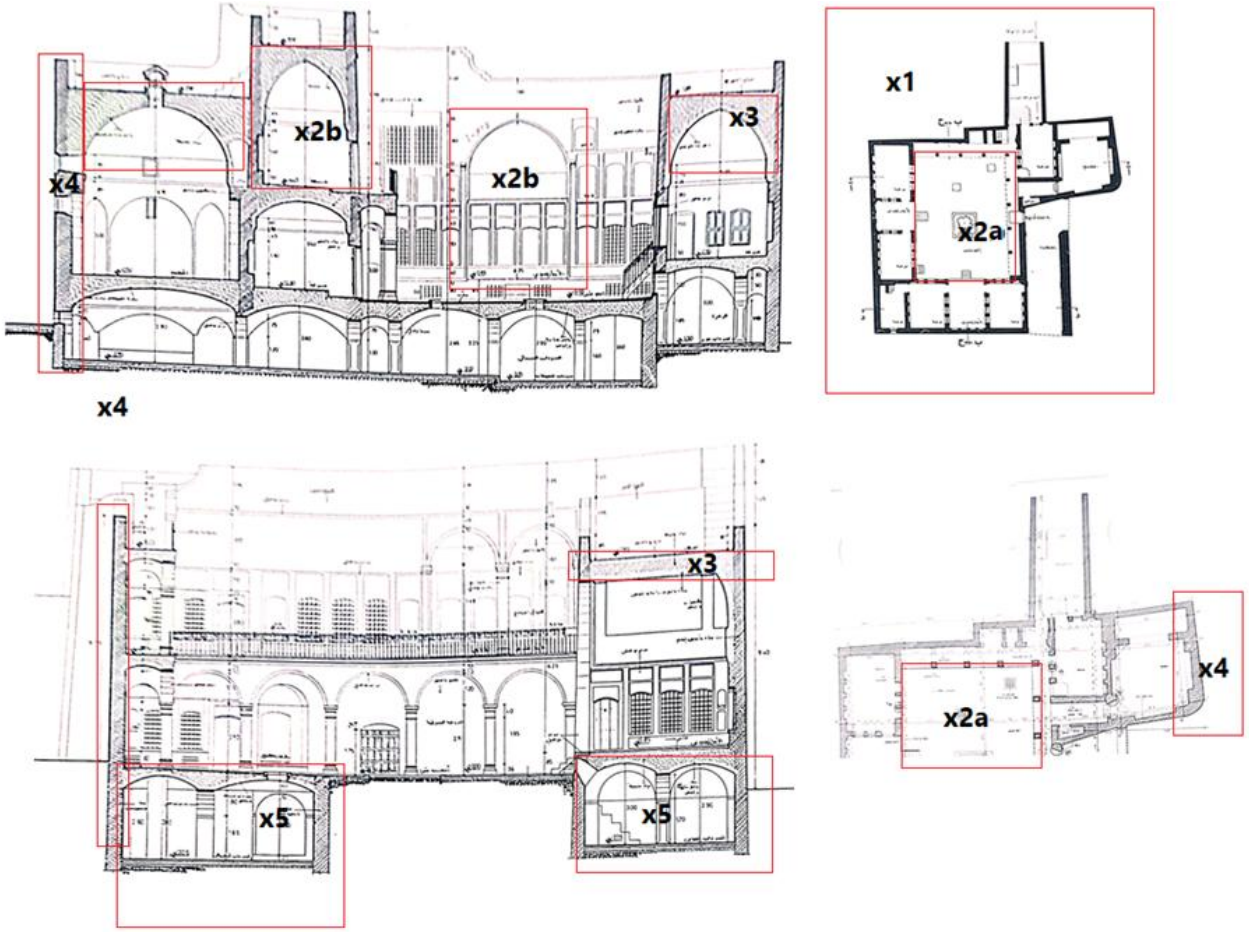

Figure 13. Principles of sustainability, Beit (House) Ziada analysis

8. Results and discussion

8.1. Results

This study clarified an architectural and environmental system rooted in the regions social values and natural context. The finding can be explained as follows:

1. Urban and Environmental Integration in the Compact Fabric of the Old Mosul City: The heritage alleys of old Mosul present a comprehensive case of the interaction between natural environment and the built environment. The organic urban pattern formed a connected network of dwellings and narrow, winding alleyways that created compact, shaded clusters. This spatial cohesion achieved environmental balance by regulating the local climate and mitigating direct sunlight, and riches social cohesion and communication among residents. The compact urban form also contributed to highly efficient land and resource use, encouraging pedestrian movement and limiting unregulated urban extended, and then reducing the Old City's environmental footprint and embodying an early model of sustainable urban development within the local context.

2. Use of Local Materials and Passive Thermal Performance: Construction relied primarily on natural materials available from the surrounding environment (limestone, fired brick, and plaster). These choices reduced transportation costs, lowered environmental impact, and fostered harmony between the built form and its natural surroundings. The thermal properties of the local stone also contributed to effective insulation and reduced energy consumption. Thick stone walls play as a thermal mass, mitigating temperature fluctuations between day and night. Courtyards with fountains and shaded terraces helped create microclimates that encouraged natural ventilation, reducing reliance on mechanical cooling and heating systems.

3. Material Efficiency and Waste Reduction: Traditional building methods emphasized reuse and minimizing waste. Stone and brick components were often recycled during restoration work, reflecting an early form of resource efficiency and circular building practices.

4. Climate-Responsive Design: The spatial organization of traditional Mosul dwellings reflects a clear adaptation to the hot, dry climate. Houses are arranged around a central (interior) courtyard, supported by natural ventilators (badgers), which promote natural air circulation and passive cooling. Thick walls also reduce heat gain and maintain interior comfort.

5. Cultural and Social Interactive: The inner courtyard formed the social core of the house, providing a space for family gatherings and hospitality while preserving privacy in an architectural response deeply connected to the social fabric of Mosul families.

8.2. Discussion

The findings focused that the sustainability of Mosul’s traditional architecture is not a product of recent environmental awareness but rather the result of accumulated local wisdom and adaptive practices. The integration of climate, natural materials, and social life has created a self-sustaining architectural model closely aligned with contemporary sustainability principles.

The organic urban pattern ensured both climatic comfort and social cohesion, riches how spatial density can coexist with livability. The use of local materials shows an understanding of ecological balance, minimizing latent energy consumption long before the concept was formally defined in sustainable design. Also, climate-adaptive features such as courtyards, badgers, and shaded walkways show that passive design was an integral part of traditional construction, achieving thermal comfort without the need for external energy.

Socially, these dwellings fostered both collective identity and privacy, balancing openness in shared spaces with seclusion in private ones a spatial to reflects. The compact form riches social interactive and reduced energy demand in urban areas, offering lessons for contemporary urban renewal projects.

Beside all of these points, the efficiently of use of materials and the preference for repair reflects reuse understanding of resources, which aligns strongly with today's concepts of a circular economy and low-carbon construction. Taken together, these insights demonstrate that Mosul's architectural heritage embodies an early and enduring form of sustainability where environmental responsiveness, social values, and the deep knowledge of construction converge in a comprehensive design language that remains highly relevant to contemporary practices.

9. Conclusions

A study of Mosul's local architecture reveals that sustainability is not a recent concept, but rather a practice rooted in the experience of Mosulian local builder, who designed an environment in harmony with the local (climate, nature, and society). This architecture combined material simplicity, environmental compatibility, and social cohesion in a model that reflects an innate understanding of sustainable living.

This heritage sustainability, due a living reference point that can imagined contemporary design practices that respect both the land and its people. When a building springs from its environment and expresses the culture of its inhabitants, sustainability is achieved as a continuation of life, not merely a technical or aesthetic goal.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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