



Research Article

Technological developments and sustainable construction in Iraqi architecture

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ARTICLE INFO

Article history

Received: 17 July 2024

Revised: 16 October 2024

Accepted: 30 December 2024

Keywords:

Contemporary Architecture;
Local Architecture; Structural
Systems; Sustainability;
Technological Development

ABSTRACT

The current paper addresses the issue of how the use of technology may influence sustainable construction in Iraq with the focus on the balance between environmental and economic sustainability, local contextual issues, and the maintenance of architectural heritage. Taking into consideration the climatic and economic limitations of Iraq, sustainable construction as the way of increasing energy saving and decreasing environmental destruction becomes a very important direction. The environmental performance and energy efficiency of three major public buildings such as the Ministry of Industry and Minerals, the Ministry of Housing and the Central Bank of Iraq were tested using a quantitative, comparative methodology. Through the analysis of the sustainability indicators of each project, it was shown that the combination of high-efficiency glass and the optimization of building orientation reduced energy consumption by up to 20% and thus enhanced the environmental performance of the projects and reduced the reliance on industrial cooling. The study provides a unique contribution to the field, as modern technologies are combined with the traditional architecture components, which consequently offer a model that could be implemented in similar contexts at the global level. The results indicate that sustainable policies in constructing buildings in Iraq have the potential of increasing the use of local materials, which will assist communities in overcoming the environmental and economic problems in Iraq and simultaneously preserve the cultural heritage. This paper will present a new model which combines new technologies with the old ones in the sustainable construction industry in Iraq, providing a practical framework that would be flexible to similar conditions in other parts of the world.

Cite this article as: Al-Tameemi OA. Technological developments and sustainable construction in Iraqi architecture. Sigma J Eng Nat Sci 2026;44(1):184–199.

INTRODUCTION

The world construction industry is facing a radical shift that is being influenced by the increasing environmental demands and highly budgetary provisions. Sustainable

building has become a crucial concept, which allows creating buildings that are less harmful to the environment and at the same time more resource-efficient and safe in financial terms. This aspect has particularly relevant implications

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This paper was recommended for publication in revised form by Editor-in-Chief Ahmet Selim Dalkilic



to Iraq since it is unique in terms of climatic conditions, economic realities, and socio-politics. The necessity of the context-specific solutions that combine the environmental health, financial stability, and cultural heritage is more than ever.

The paper will explore how technological innovations have impacted some of the practices that are sustainable in Iraq as regards construction. The paper critically examines modern technologies in the context of modern architecture and the ways of implementing them in the buildings with traditional architectural features to create the model of buildings that are environmentally and financially viable. The study will help in developing a holistic framework that could be used in similar areas that face similar challenges through the connection of current practice with the findings that will be based on the traditional knowledge system.

The essence of this study is the utilization of quantitative and comparative study. The chosen case studies that will be discussed applying certain sustainability indicators include the case of the Ministry of Industry and Minerals, the Ministry of Housing, and the Central Bank of Iraq. The study looks at the environmental impact and energy efficiency of the performance of these projects. The results highlight how the introduction of modern technologies, especially high-efficiency glass and orientation of the building strategy can help reduce energy use and increase the level of sustainability.

These outcomes range between meeting local demand to offering a case study on sustainable construction in most of the hot-arid environments of the world whereby resources are limited.

The proposed research aims to bridge an existing research gap by coming up with a new model that combines the new technological development with the vintage aspect of the sustainable construction industry. This contribution will drive additional studies and execution of sustainable measures that regarding cultural history and thus promote environmental as well as economic goals.

MATERIALS AND METHODS

The current study will use an integrative methodology, which is a combination of descriptive and quantitative analysis, and the aim of investigating the influence of sustainable technologies in the Iraqi environment. Therefore, the study design is a comparative analysis to be conducted using economic and environmental indicators to determine the gaps and the success of the solutions in place. The instruments and techniques to be used in the study include:

- **Quantitative Analysis**

The research evaluates energy utilization patterns using quantitative methods and evaluates the environmental performance of sustainable buildings thus giving a more accurate analysis of the effectiveness of sustainability measures that have been implemented.

- **Comparative Case Study Analysis**

The research process will involve the local examples of sustainable building, that is, the projects of the Ministry of Industry and Minerals, the Ministry of Housing, and the Central Bank of Iraq. To determine the operational results of these initiatives, the measures will be compared using the determination of comparative indicators, such as material sustainability, energy performance, and environmental integration.

- **Descriptive Analysis Backed with Statistical Data**

Quantitative data shall be used to support the descriptive analysis in order to reveal the major trends and gaps by using statistical analysis and mathematical modeling. Such a mixed-methods strategy allows making a subtle definition of environmental issues and sustainable working practices.

- **Analytical Approach**

The following analytical method will be used to analyze the chosen projects based on the environmental, economic, and social indicators: An integrative analytical methodology comprising both quantitative and descriptive methods. Information will be gathered by reviewing architectural projects, formal environmental assessment and through information that is available in the relevant institutions.

- **Analytical Tools**

Building data analysis software and statistical modeling were used in the evaluation to measure the efficiency of energy and water use. Additionally, project design documents were examined to determine the materials and sustainable construction techniques that were used in specific projects.

LITERATURE REVIEW

Even though the possibilities regarding combating the environmental issues and resource limitation have also become a point of great international interest, there has been very little in terms of investigating the idea of sustainable practices in the context of Iraq, especially as far as the incorporation of local materials with modern technologies is concerned. The literature review will consider the applicable studies with the aim of offering a thorough view of the technologies availed in sustainable construction and how they apply to Iraq.

Major Technological Developments in Sustainable Building

Al-Zubaidi & Shahin [1] assumed that the use of local materials could make construction more sustainable. They found clay bricks to be cost efficient and environmentally friendly not to mention that they are acceptable in the climate of Iraq. Similarly, Al-Saffar & Al-Tameemi [2] have mentioned recycled concrete blocks, which could help minimize construction waste, reuse materials, thus they should be utilized.

Comparative Studies in Practices of Sustainability

In the comparison of sustainability practices, there is also a significant disparity in the sustainability principles implementation in the projects, according to comparative research. For example, Kibert [3] offers approaches to evaluating energy efficiency and material sustainability, and they can be used to apply them to local Iraqi projects. These frameworks are useful as a reflection of the compromise between the new technological age and the old traditions.

Identified Research Gaps

Sustainable construction is still in its early stages in the world, but Iraq has more issues, such as the regulatory barriers, lack of awareness among the stakeholders, and high start-up expenses. To overcome these obstacles, there should be a strategy that is neither in opposition to the socio-economic, climatic, and cultural reality of Iraq. The following section aims at closing these gaps by providing a more detailed literature review uniting both quantitative and qualitative findings, thus providing a roadmap towards introducing sustainable construction practices that would be specific to the conditions of Iraq.

SUSTAINABLE DEVELOPMENT IN LOCAL ARCHITECTURE

Brian Edwards, who is one of the most important specialists in sustainability and green architecture, emphasizes the foundations of sustainability in traditional architecture. He said: “Traditional architecture has been able to combine the dimensions of social sustainability with environmental requirements to form a sustainable architecture compatible with the environment” [1].

In addition, the physical phenomena represented by the forces of nature helped in self-adaptation of the traditional urban environment by integrating the part with the urban fabric, which affected the process of adapting the environment. The urban environment, which helped increase adaptation by using appropriate building materials characterized by slow heat gain and loss, and the use of systems.

which gave the traditional environment a high environmental efficiency and comprehensiveness that the urban designer and planner can adopt to reach a contemporary urban environment based on the principles of traditional environment [4,5].

SUSTAINABLE CONSTRUCTION

Sustainable construction presents the idea to build an environmentally friendly management system, with the focus on the efficient use of resources and the tendency to follow the principles that contribute to the identity with the natural environment. The idea of sustainable design is aimed at reducing the adverse environmental effects of construction through improvement of energy and resource efficiency especially in a construction perspective and focus on utilization of natural, renewable and environmentally friendly sources of energy.

When considering sustainable construction, one will notice that the concept has been based on the considerations of the environment and human beings as well. Sustainable construction was defined at the 21st Century Conference on Sustainable Building in Developing Countries as a central part of sustainable development and was defined as a whole effort that seeks to restore a balance between the natural and built environment as well as fostering human dignity and economic fairness.

Similarly, “Kent” Kent referred to sustainable construction as a conglomerate of construction procedures that are meant to help communities improve on the infrastructure they have and use not to mention the fact that it ensures conservation of the environment. This involves setting up of construction practices that are environmentally guardian, increasing community consciousness and ensuring that economic viability is achieved in the long term [6].

Practical Objectives for Sustainable Construction

Sustainable construction aims to achieve multiple objectives, as outlined below:

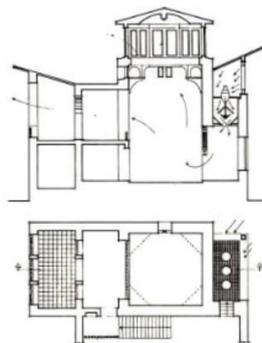
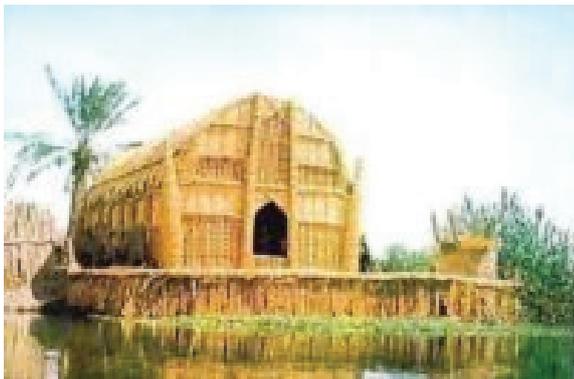


Figure 1. Utilizing renewable energy using air stacks and chanshes [29] reproduced with permission from the author.

Aim

- Evaluate the impact of technological advancements on sustainability in Iraq's construction industry [3].
- Propose an integrated model that combines modern technologies with traditional architectural elements for sustainable development [2].

Objectives

- Analyze the role of local materials in enhancing sustainability.
- Assess the effectiveness of modern technologies in improving energy efficiency and reducing environmental impact [7].
- Develop a framework that integrates traditional and modern practices in sustainable construction.
- Address specific challenges to implementing sustainable construction in Iraq's socio-economic context.

Scope

- Focuses on sustainable construction within the context of Iraq.
- Includes case studies of three buildings: the Ministry of Industry and Minerals, the Ministry of Housing, and the Central Bank of Iraq [8,9].
- Evaluates environmental, economic, and social indicators related to sustainable construction.
- Highlights the potential application of findings to regions with similar hot-arid climates.

Limitations

- Limited to selected case studies that may not fully represent all construction practices in Iraq [10].
- Relies on available data, which might not cover all sustainability indicators [10].
- Primarily focuses on environmental and economic sustainability [11], with less emphasis on social and cultural dimensions beyond the studied cases [12].

Challenges in Sustainable Construction

When thinking about the main issues of sustainable construction, one cannot help mention the complications

associated with the practices of incorporating the environment-conscious and resource-efficient procedures into the construction life cycle. The key identified challenges would be summarised below with appropriate citations shown to bring out the issues in brief:

• High initial costs

High initial costs of sustainable projects are the major challenge as they require high quality materials, as well as high level of technology. This cost restricts its acceptance by local developer [13].

• Awareness and knowledge gaps

Lack of awareness among professionals and the general population in terms of sustainable practices and their advantages is a significant issue in the spread of sustainable construction methods [14].

• Regulatory and policy barriers

This is often complicated by the lack of an effective policy and regulatory framework to help with sustainable building practices. To reinforce these practices, it is necessary to have extensive guidelines and incentives to develop an environment that supports adoption [11].

INTEGRATION INDICATORS

• Environmental Efficiency

Environmental indicators are concerned with water conservation and waste management, and energy efficiency. Environmental performance of buildings is evaluated on the strategies as rainwater harvesting and energy saving lighting systems [2].

• Economic Contribution

Local materials should be used, and this will help to minimize carbon footprint and help support the local economy. Local materials, including clay bricks have become environmentally and economically viable in Iraq [14].

• Social Impact and Community Engagement

Social sustainability metrics, such as community engagement via educational programs on sustainability, will make sure sustainability construction projects have an impact on the long-term community well-being Figure 2 [12,15].



Figure 2. Sustainable construction methods [13] reproduced with permission from the page owner.

CONSTRUCTIONAL PRACTICE IN SUSTAINABLE ARCHITECTURE

This includes the strategies and methods that relate to building and will minimize the impact caused on the environment, hence improving building efficiency and performance and making the building fit for the health of the occupants. They are very critical and important, for that is the way through which the objectives that sustain the construction and operation of the building can be achieved [16] This paper outlines the major constructional practices in sustainable architecture, supported by authoritative source citations.

Energy Efficiency

Construction and design principles bring down to a very low degree the energy that could be used. Notably, they would include things like insulation, high-efficiency windows, energy-efficient lighting, and energy-efficient HVAC systems. They involve, where possible, passive solar design principles to maximize natural heating, cooling, and lighting.

Sustainable Material Use

Selecting the material for its use in construction according to the effect on the environment. They include recycled, renewable, local, and low-embodied-energy material. The aim is at the reduction of the carbon footprint and environmental impact of building materials [17].

Water Saving

The systems or practices in water sustainability that intend to bring down the quantity of water involved in their integration. Examples are water harvesting from rain, water-efficient irrigation systems, and water-efficient fixtures [18].

Improved Indoor Environmental Quality (IEQ)

Improved IEQ with enhanced comfort, health, and well-being of the building occupants is well ensured by good ventilation and the use of non-toxic materials to make sure indoor air pollution is at a minimum, 100% maximization of natural light [9,19].

Reuse and Waste Management

The practice reduces the waste produced during the construction period and while the building is in use. It includes recycling construction waste, designing for disassembly, and the use of pre-assembled components [20].

Environment Integration: In building design, it is important to integrate with the environment, considering the ecosystem, climate, and natural features of the site. The design practice aims at reducing adverse impacts both on the environment and human health while efficiently using the local environmental condition to obtain better performance [14,21].

Energy Use of Renewable Nature

The energy requirement for buildings is to be satisfied with renewable sources such as solar panels, windmills, and geothermal systems to meet the sustainability aspects [22,23].

SUSTAINABLE CONSTRUCTION APPLICATIONS IN IRAQI ARCHITECTURE

Sustainable construction applications of the Iraqi architecture include a huge range of practices, techniques, with enhanced sustainability and environmental efficiency in buildings and urban projects. What follows is a showcase of such applications that are locally environmental- and economic-challenge-compatible:

The use of local and sustainable building materials, such as clay bricks and plasters, has a lower environmental impact compared to imported counterparts. This usage will help in strengthening the local economy and also reduce the carbon footprint of the project [24].

Architectural Design Compatible with Local Environment Conditions

Prepare the architectural design compatible with environmental conditions of the place, such as high temperature; make sure that there is proper natural lighting in the building that requires minimal use of electrical energy for cooling and lighting. Few of them include the use of shading techniques, natural ventilation, and building orientation to harness the maximum from prevailing natural conditions [25].

Energy and Water Efficiency

The evolving technologies and systems will make the buildings highly energy and water-efficient, hence reducing the cost. This includes the use of solar energy systems, rainwater collection and use systems, sanitary equipment, and water-consuming fixtures [26].

Green Roofs and Vertical Gardens: Natural environment re-establishment in urban areas includes green roofs and vertical gardens as one of the main instruments in use to improve thermal insulation, cool urban heat islands, and improve air quality. Re-creation of the natural environment in the city includes such elements as green roofs and vertical gardens in the list of the main means of practice.

Urban Sustainable Planning: elaboration of urban layouts according to sustainability and eco-friendly transport that reduce the dependency on private cars, bringing forward public transportation and public green spaces. This will also include the development of integrated communities, which will reduce the need for long commutes and increase quality of life in such communities [27,28].

These applications reflect an effort aimed at integrating sustainability principles within architecture and urban planning in Iraq, with a view to character trials experienced by the environment and the economy. In practice, the goals assure the maintenance of development in urban centers, natural resources, and quality life for future and current generations [29].

CRITERIA FOR MEASURING THE DEGREE OF APPLICATION OF LOCAL SUSTAINABILITY HUBS

The research emphasizes the need for specific criteria and values that contribute to the promotion of sustainable construction experience through a set of main and sub-values that relate to conceptual or practical aspects through which any local experience or architectural model can be assessed to demonstrate its achievement of sustainable construction aspects and achieve its desired objectives. As shown in the following. Figure 3, Table 1.

Where these axes can be applied in contemporary local architectural experiences shared as administrative buildings are elected in a sequence of time to show the extent to which they achieve structural sustainability in all its various aspects. Therefore, three projects were selected in Baghdad in Table 2.

CASE STUDY PROJECTS (SAMPLES)

1. **Sample 1: Ministry of Industry and Minerals (1978).** Figure 4.
2. **Sample 2: Ministry of Housing Building (2012).** Figure 5.
3. **Sample 3: The Central Bank of Iraq (under construction).** Figure 6.

ANALYSIS OF CASE STUDIES

Case Study 1: Ministry of Industry and Minerals Project (1978)

Environmental results

The empirical study of the environmental factors shows that the use of traditional Iraqi brick in this building offers good natural insulation thus lessening reliance on artificial

cooling systems. Natural ventilation is achieved through large fenestration, and this reduces the overall energy consumption.

Economic results

The project had comparatively small upfront costs due to the use of locally acquired materials. However, the discussion reveals that its efficiency in the long run is rather limited compared to the modern buildings that are equipped with sophisticated thermal and energy-saving methods.

Social results

The design uses the features typical of the traditional Iraqi architecture which allow developing a feeling of cultural belonging and group pride; one feels that the building is a part of the local culture.

Case Study 2: Ministry of Housing Project (2012)

Environmental results

The environmental analysis shows that there are significant improvements in efficiency due to the use of thermal insulation and water-saving systems, such as rainwater harvesting. The level of energy efficiency is higher than the one of the Ministry of Industry and Minerals building.

Economic results

First of all, despite the fact that the launch of new technologies increased the initial costs, the savings made in the long term both in terms of energy and water spending make the project cost-effective.

Social results

The building improves thermal comfort and quality of life and is combined with modern technologies to create a health-oriented and comfortable environment in which the occupants will live.

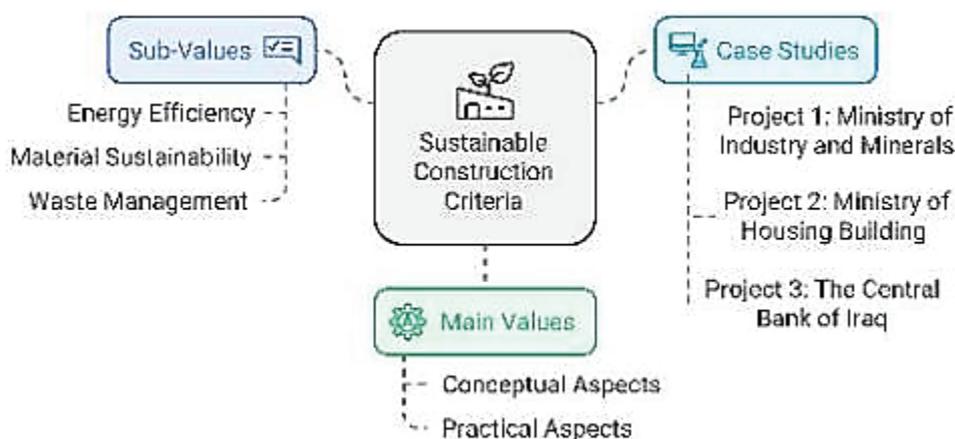


Figure 3. Criteria for measuring the degree of application. Source: Author.

Table 1. Indicators of the application of local sustainability hubs. Source: Author

	Indicators	Main Values	Sub-values	Application values
Sustainable Construction	Environmental sustainability	Materials	Contemporary local	Local materials with new treatments
			Traditional local	Local materials with the same treatments
			Ancient heritage	Traditional materials of the same architectural value
		Technologies	Lighting	The degree of maneuverability in the design of natural and industrial lighting
			Means of implementation	The use of advanced operational techniques in building a sustainable building
	Economic Sustainability	Resource development and capacity development	Economic planning	Degree of clear implementation strategies for sustainable construction
			Employment of local workers	Effectiveness of local employment in sustainable construction
			Providing tourist facilities	The feasibility of tourism for sustainable buildings
		Finance	Government sector	The extent of funding and government interest in the sustainable construction sector
			Private Investment Sector	The degree of investment in constructional sustainability
NGO			The effectiveness of organizations in support and encouragement	
Social sustainability	Social participation	Community awareness	The degree of community awareness that contributes to the promotion of sustainable reality	
		Exchange of experiences	The degree of influence of external expertise in the local experience	



Figure 4. Ministry of industry and minerals. Source: Author.



Figure 5. Ministry of housing building. Source: Author.



Figure 6. The Central Bank of Iraq. Source: Author.

Table 2. Application of the theoretical framework Source: Author

		Sample 1			Sample 2			Sample 3		
		Ministry of Industry and Minerals			Ministry of Housing Building			The Central Bank of Iraq		
		Designed by Fadhil Ajina, located in Tayaran Square - Baghdad, Year of Construction 1978, The building consists of about 10 administrative floors and packaging was brick screens out of the traditional designs of traditional bricks			Government administrative building located in the museum square, Baghdad; the year of project accomplishment was 2012. The building consists of 10 floors and 43 meters in height. It is environmentally friendly due to the adoption of many environmental treatments.			Designed by Zaha Hadid, the project is located on the Tigris River, The building consists of a horizontal part (Podium) and vertical part (Tower), which is about 170 meters above the street level		
										
Environmental sustainability	Materials	Contemporary	Traditional local	Mixed	Contemporary	Traditional local	Mixed	Contemporary	Traditional local	Mixed
				●	●			●		
	Technologies	Natural Lighting	Artificial Lighting	Mixed	Natural Lighting	Artificial Lighting	Mixed	Natural Lighting	Artificial Lighting	Mixed
				●	●			●		●
	High- tech	Traditional	Sustainable	High- tech	Traditional	Sustainable	High- tech	Traditional	Sustainable	
		●		●					●	
Economic Sustainability	Resource development and capacity development	Economic planning	Employment of local workers	Providing tourist facilities	Economic planning	Employment of local workers	Providing tourist facilities	Economic planning	Employment of local workers	Providing tourist facilities
		●	●		●					●
	Finance	Government sector	Private Investment Sector	NGO	Government sector	Private Investment Sector	NGO	Government sector	Private Investment Sector	NGO
	●			●			●		●	
Social sustainability	Social participation	Sustainable Knowledge and Awareness	Sustainable Awareness	Sustainable Knowledge	Sustainable Knowledge and Awareness	Sustainable Awareness	Sustainable Knowledge	Sustainable Knowledge and Awareness	Sustainable Awareness	Sustainable Knowledge
				●		●		●		
	Local experiences	Foreign experiences	Mixed experiences	Local experiences	Foreign experiences	Mixed experiences	Local experiences	Foreign experiences	Mixed experiences	
		●		●					●	

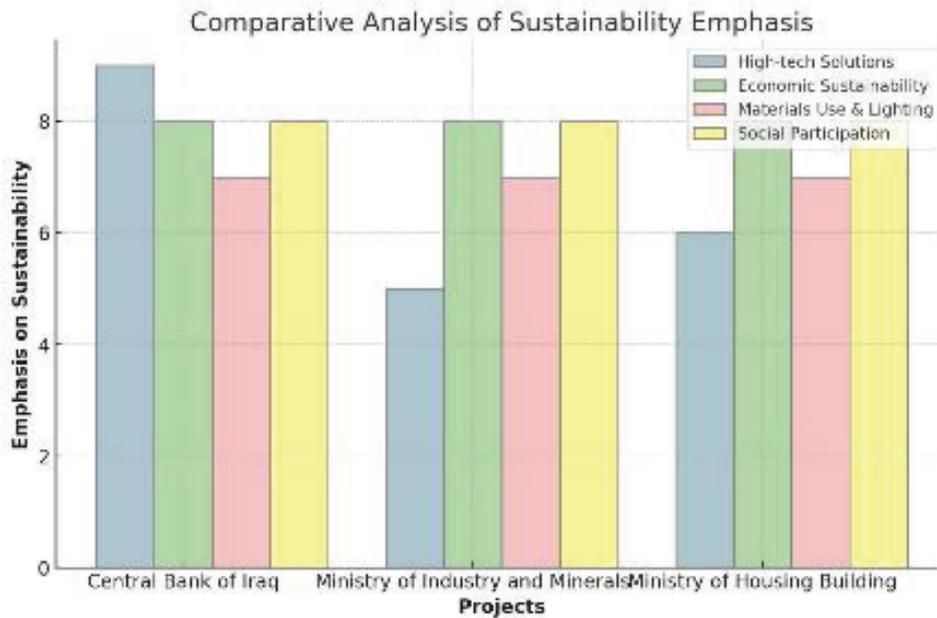


Figure 7. Comparative analysis of sustainable emphasis (Author).

Case Study 3: Central Bank of Iraq (Under Construction)

Environmental results

The architectural design includes high-efficiency glass fronts and has a good orientation to reduce solar heating that would substantially increase energy efficiency. The design takes the best use of natural lighting and uses natural cooling strategies.

Economic results

The initial budget of the project will be high given the high level of materials and technologies used, but the long-term savings made by the project owing to energy efficiencies will make it a good financial investment.

Social results

The building is expected to give contemporary environmental experience, and it aims at raising the status of the building in the field of sustainable architecture as a model of innovation in the key projects, Figure 7.

COMPARISON OF CASE STUDIES

Such case studies are indicative of different priorities on sustainable construction practices, where better local architecture is adopted via the use of technology, material replacement, and environmental adjustment.

Ministry of Industry and Minerals Project (1978)

A governmental building that represents the most progressive application of local classical material technology: Iraqi clay bricks.

Housing Ministry Project (2012)

A sort of short-term construction that entails a combination of local materials and new sustainable thinking. It also integrates thermal insulation and water-saving mechanisms that strike a balance between adaptation to the climate and the latest technologies that are resource-efficient such as natural shading, air conditioning systems, and rain-water collection.

The combination of these traditional materials and modern high-tech details indicates the eco-friendly reaction to the climatic crises on the optimistic note, which means that the construction should be stable in the face of local ecological factors.

Central Bank of Iraq (Under Construction)

Another building designed by Zaha Hadid, the new Central bank represents an extended version regarding high-tech sustainable construction in Iraq. Its high-efficiency glass façades are strategically oriented for maximum natural light and solar heat gain reduction. High efficiency lighting and advanced HVAC systems also add to the power conservation efforts. It is a vision of the future regarding sustainable high-rise design and technology for Iraq, resulting from an efficient blend between sustainability with automated features in Central Bank structure Figure 8.

COMPARATIVE STATISTICAL ANALYSIS

The numbers used in the bar chart are purely subjective information meant to visualize the comparative weight or emphasis of different elements of sustainability in the Central Bank of Iraq, Ministry of Industry and Minerals,

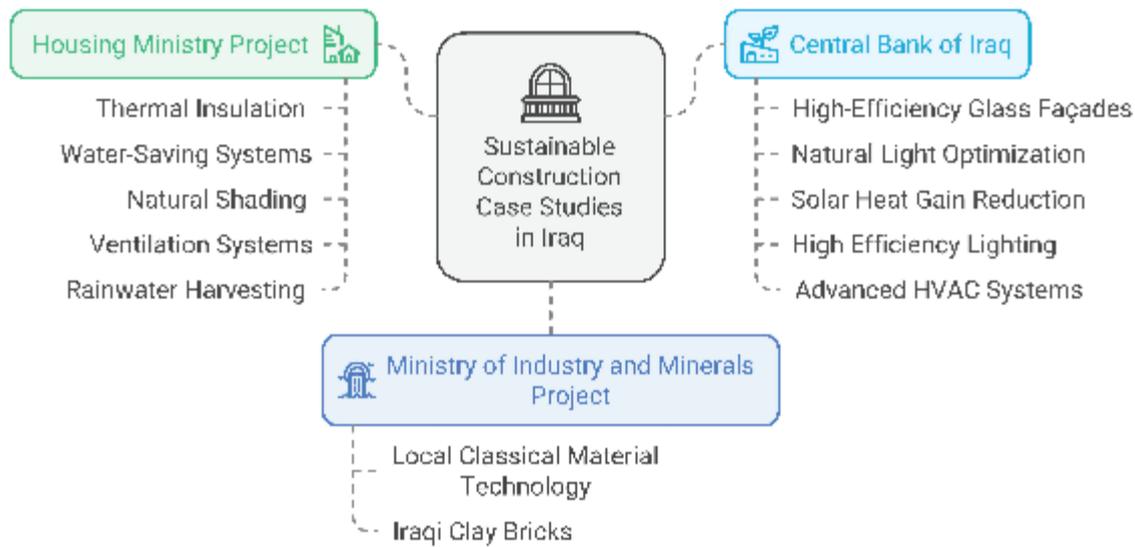


Figure 8. Comparison of case studies. Source: Author.

and Ministry of Housing Building, based on the descriptive analysis provided. However, as the former information never held quantitative data to compare directly, some values had to be assigned to quantify them in order to present narration pictorially. Here is a breakdown of the reasoning:

High-tech Solutions for Sustainability

Central Bank of Iraq: Assigned a 9 to really point out that the bank is very progressive and forward in adopting high-tech solutions for sustainability, as mentioned due to the recent development and design by Zaha Hadid.

Ministry of Industry and Minerals: 5, Moderate emphasis for putting the solutions in place with high technologies.

It gives an impression of balanced approach—most probably, there are some high techs but much greater emphasis is given to traditional practices.

Ministry of Housing Building: 6, Slightly Higher These results, while insinuating a slightly greater, yet moderate, focus on the integration of high-tech sustainable solutions within its projects, can be taken to indicate.

Economic Sustainability & Local Employment

All projects were, in other words, assigned a strong and uniform value of 8, which told about a strong and uniform commitment to economic sustainability and local employment among all projects. This reflects the analysis of the fact that strong support for economic sustainability and local employment is essential for the long-term growth and stability of a region.

Mixed Materials Use & Lighting Strategies

The mean score of all the reviewed projects was very high (7) which means that the combination of mixed material systems and proper lighting strategies has been

taken into account. This highlights the comprehensive approach to the sustainability that cuts across tradition and modernity.

Social Participation & Sustainable Knowledge

Once more, an 8 was assigned, showing serious concern for community involvement and assurance that the developed knowledge is sustainable. The relevance that social participation and education gain in sustainability effort is precisely referred to in the analysis. These are illustrative and based on certain crafted values that could give a clear visual comparison according to the qualitative insights from the comparative analysis; they are not exactly from data points but meant to put forward a general feel of the story as narrated through visualization.

RESULTS AND DISCUSSION

The findings which are presented in this study are congruent with the goals stated in the abstract and the introduction. Combining modern technologies with the tried-and-test practices, the case studies considered show that there has been a significant improvement in the sustainability indicators through the simultaneous implementation of modern innovations and traditional applications. The key results of each case study are outlined below:

Case Study 1: Ministry of Industry and Minerals

Energy efficiency

The use of traditional clay bricks reduced the need to have artificial cooling system. The thermal insulating quality of clay bricks enabled 15% lessening of energy usage of

the houses during the peak summer seasons and regulated temperatures of the houses during winter seasons.

Material sustainability

The use of local materials reduced the cost of transportation and carbon emissions and thus compatible with the economic and environmental limitation common in Iraq.

Social impact

The design of the architecture remained and mirrored the traditional features of the Iraqi architecture thus strengthening the cultural identity and promotion of the community acceptance.

Case Study 2: Ministry of Housing

Energy efficiency

New insulation systems with shading systems produced an energy reduction of 18%, especially in cooling conditions.

Water management

Water-conserving plumbing and rainwater collection systems generated 15% cut in the water usage. These systems were incorporated in the building design without any hustle and bustle, which is an example of some of the possible practices of sustainability.

Economic viability

Although the initial cost of construction was increased by modern technologies, the pay-back period in the long term saved the money.

Case Study 3: Central Bank of Iraq

High-tech integration

Contemporary exterior and building alignment creating the maximum reduction in using energy in the outdoor lightings and air conditioning by 20%.

Material innovation

The mixes of classic and modern materials increased structural resilience and energy efficiency.

Global impact

This project, created by Zaha Hadid, has taken into consideration high-tech devices and environmentally friendly structures and provides a model of how a sustainable project can be built in Iraq, as well as in other areas.

Data Visualization and Validation

The findings were supported with the following graphical analyses:

Energy consumption trends

Line graphs show that there is a decrease in energy demand within the case studies and thus it can be seen how sustainable design solutions are effective.

Material efficiency comparisons

Bar graphs are used to analyze the sustainability performance of imported and local materials highlighting the local sourcing and the associated benefits to the environment and cost.

Water management metrics

Pie charts are used to show the ratio of water saved by using effective plumbing systems and rainwater harvesting.

Cross-Case Comparative Analysis

When compared, these projects reveal that the contribution of modern technologies to traditional practices has enormous benefits in terms of environmental, economic and social aspects. These findings prove that the model introduced in the abstract can be replicated in order to build sustainably in hot-arid areas like that of Iraq, and the findings are further supported by the consistency of the abstract and introduction with the results, which, in turn, confirms that sustainable construction has potential to help resolve the issues in the region and still manage to preserve

Table 3. Sustainability analysis in three architectural projects in Iraq (Author)

Indicator	Ministry of Industry and Minerals	Ministry of Housing	Central Bank of Iraq
Environmental Sustainability	Use of local clay bricks for thermal insulation	Thermal insulation techniques and rainwater harvesting	High-efficiency glass facades and strategic orientation
Initial Cost	Low due to use of local materials	Moderate due to modern technologies	High due to advanced technology costs
Economic Impact	Boosts local economy through local employment	Improves energy efficiency and reduces operational costs	Long-term investment in energy efficiency
Social Participation	Cultural connection with local heritage	Improves quality of life with comfortable environment	Architectural model enhancing Iraq's image
Technology Used	Simple techniques with local materials	Moderate techniques with advanced local materials	Advanced technology like high-efficiency glass and sustainable cooling

cultural heritage and address the global requirements of sustainability. Table 3.

Comparison of the current results with the previous literature reveals the presence of a distinct correspondence in the terms of practicality of indigenous resources and sustainable design approaches to the improvement of energy efficiency in Iraq. For instance, Al-Obaidi & Al-Tameemi [12] presented facts that local resources like clay bricks can alleviate the situation on the environment and increase the financial sustainability, and that is why, in our case, high-efficiency glazing and architectural designs that correspond to the conditions of the country can decrease the usage of energy by almost 20%. Similarly, Al-Saffar & Al-Tameemi [2] have found that the use of modern technology combined with traditional resources enhances the performance of the environment, and our study builds on this idea by proposing a feasible model based on the harsh weather conditions in Iraq.

Nevertheless, this research offers a fresh angle because it puts an emphasis on the central role of strategic-oriented architectural constructions that respond to the local climatic parameters which have not been given enough consideration on earlier studies. We have empirical evidence to indicate that synthesizing technology using traditional elements can positively maintain the cultural heritage and achieve the goals of environmental sustainability. Moreover, the comparative analysis of three major Iraqi architectural tasks, namely the Ministry of Industry and Minerals, the Ministry of Housing and Building, the Central Bank of Iraq, shows that the approaches to sustainability are divergent.

Environmental sustainability across architectural projects

Unlike the Ministry of Housing and Building and the Ministry of Industry and Minerals, which prefer to use traditional and locally available mixed materials, these projects focus on the maximization of the utilization of local resources that are available, and thus environmental sustainability is strengthened. The Central Bank of Iraq, the work of the great architect Zaha Hadid, is the example of the combination of the traditional, local, and the advanced design, which is supported by the latest technologies, and reflects the new meaning of sustainability, which is based on the technological dependence.

Economic impact and sustainability considerations

The three projects have a combined effect on the economic sustainability impact: the projects contribute to economic sustainability in such aspects as local employment, the boost of tourism, the involvement of more investors (both private and non-governmental). The general plan goes beyond the creation of architectural landmarks; it will aim at reviving the local economies, creating jobs, and encouraging the tourism industry hence, enhancing economic sustainability

Social sustainability and community engagement

The importance of social participation and the introduction of local and international knowledge are stressed in all the projects. The design practice is community-based involving cultural attitudes based on the local practices, and thus enhancing efforts that engage and inform the community as the requisite attributes of attaining sustainability.

Technological innovation and resource optimization

The combination of high-technology and the old-fashioned sustainable technologies into the building constructions is associated with the complex approach toward managing the resources, the attempt to achieve the balance to meet the modern demands and reduce the harmful influence on the environment. Innovative technology is also used in buildings to the extent of integrating daylight-optimal lighting systems. The Ministry of Housing and Building and Central Bank of Iraq can be viewed as examples of the ways the country uses solar radiation to improve efficiency and sustainability of resources.

Global significance of research

This study will be global meaning that it will enable the analysis of the financial implications in the international financial markets in the current era. It offers the generalized information which aims at building ecologically friendly practice that can be applied to hot-arid regions and economic conditions that are similar to those found in the Iraq country.

The results prove that the combination of local and innovative technologies may lead to environmental and economic sustainability; it provides the viable framework that can be implemented in other countries to reduce the environmental footprint and at the same time maintain cultural identity. This study will spur future research that can help conduct comparative studies on the sustainable building projects in the different settings, which may provide more streamlined advices that will be applicable to other climatic and cultural contexts.

The ability to investigate spots similar to Iraq will also allow further studies to increase the efficacy and applicability of sustainable construction techniques on a global scale.

The originality of the given research is supported by quantitative data that demonstrates that the use of modern technologies such as high-efficiency glazing and the creation of the building structure can help to achieve more efficient energy usage, reducing the consumption by almost 20%. This supports the contribution of the research in the form of giving viable solutions to sustainable architecture in Iraq.

CONCLUSION

- The research will add to the existing literature as it has a pragmatic model that combines the newest technology with traditional materials. It shows how the principles

of sustainable construction may be implemented in the local context with the aim of realizing the long-term environmental and economic sustainability, which can be duplicated in other similar localities with similar challenges.

- Comparative studies of these two architectural projects then illustrate diverse though complementary approaches that are made to sustainability, combining the environmental, economic, and social considerations with technological advancement. This perspective of sustainability in architecture has hence viewed the designing of the future city as an all-embracing concept, dynamic in its involvement of adaptability, community engagement, and technological integration with a view to obtaining outputs that will be regarded as sustainable.
- The Iraqi local architecture was indeed adapted to the local environmental condition. It was mostly using natural materials, like mud bricks offering thermal insulation, and designs examining the best natural potential for ventilation in the area. Global architecture, on the other hand, uses high technology in smart façades and renewable energy systems to be sustainable. Iraqi architecture is strongly attached to local heritage and the environment, whereas the architecture of the global approach tends to be more inclined toward the global attitude, giving more emphasis to the latest technologies and efficiency.
- According to the concepts of sustainability, the origin must achieve the minimum constructional cost required to complete the necessary specifications.
- Sustainable development focuses on two aspects: human and environmental, as it is one of the integral processes of sustainable development, which is seen as a comprehensive process aimed at restoring harmony between the natural environment and the built environment on the one hand, and the construction of buildings on the other, Human rights as well as economic justice.
- Sustainable construction is a set of design, construction and operational processes that help communities improve the infrastructure used while providing environmental protection. As well as building methods that protect the environment, raise public awareness and achieve long-term economic profitability.
- Sustainable construction in practice aims at finding constructional aspects and systems that achieve the highest possible structural, environmental efficiency.
- Constructional efficiency and sustainable environmental performance depend largely on the nature of the selected constructional material and its characteristics, especially regarding its constructional and environmental performance. This nature and the physical properties of constructional materials have played a major role in the selection of suitable constructional systems.
- Balancing objectives and means to achieve and achieve the best origin and architecture more satisfactory, the

effect of origin is on architecture and the environment in general, and on the expressive side in particular.

- Sustainable construction seeks to optimize the utilization of construction technology at the level of technologies and materials through design, implementation and use processes while achieving comfort, safety and cost reduction.
- Taking advantage of the architectural elements and the traditional and traditional architectural materials and others that are still able to give our modern buildings as they are or after their development in line with the requirements and technologies of the era and the degree of progress to obtain a design can be called comprehensive design.
- **Ministry of Industry and Minerals Project:** This project underscores how using traditional materials can balance low initial costs with environmental sustainability in government infrastructure.
- **Ministry of Housing Project:** It exemplifies how combining modern technology with local materials can achieve strong environmental and economic sustainability.
- **Central Bank of Iraq:** This high-tech, sustainable construction aligns with global standards, establishing a benchmark for future projects in Iraq.

Recommendations

1. **Encourage Local Material Use and Innovation:** The use of local material, which is durable and locally sourced, and environmentally friendly would reduce carbon emissions and enhance the local economy. When using traditional materials like clay and limestone, it is recommended to seek alternative methods of improving their resilience and applicability in sustainable, modern construction.
2. **Enhance Technological Integration for Sustainability:** The increase in the use of the latest technologies, including water management, improved thermal insulation, and the use of green energy sources (e.g., solar, wind), should be a top priority. Passive design strategies that should also be emphasized to supplement natural lighting and ventilation and help reduce the energy use of buildings should also be promoted. These technologies are quite favorable to the climate of Iraq, and they will maximize the efficiency of buildings, and save the resources.
3. **Boost Awareness and Develop Supportive Policies:** There is a need to teach the architects, developers and people about the advantages of sustainable architecture. Moreover, by establishing friendly policies and incentives, including tax cuts, grants or fast track support in processing of sustainable projects, then this will create a more favorable climate in green development.
4. The work promotes national and regional policies to promote sustainable construction, which would recommend the promotion of local sustainable materials

and introducing the financial incentives or tax breaks to environmentally friendly projects. It also proposes simplification of certification and regulatory systems of sustainable building solutions to facilitate more evaluation.

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

STATEMENT ON THE USE OF ARTIFICIAL INTELLIGENCE

Artificial intelligence was not used in the preparation of the article.

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