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SUSTAINABILITY INVESTIGATION OF THE OLD MUSTANSIRIYA MADRASA IN MODERN CONSTRUCTION: A COMPARATIVE STUDY

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ABSTRACT

This paper explores the sustainable concepts performed in the Old Mustansiriya Madrasa constructed in Baghdad during the Abbasid era in the thirteenth century AD. The principles and main techniques of sustainability used for modern buildings were compared with the design concepts implemented in the Old Madrasa to extract the most significant concepts that could be applied in designing modern school buildings. The findings showed that the Mustansiriya Madrasa was a distinctive example of Islamic architecture, which included sustainable features. It contained sustainability concepts derived from Islamic teachings and the Holy Quran. The design concept depended on a rectangular shape with a central hollow courtyard for improving natural ventilation and lighting. The Madrasa location was chosen on the Tigris River bank, and landscaping inside and near the building provided natural cooling, air circulation, and filtering. Thick brick walls provided thermal mass techniques to benefit solar energy. Skylights in the narrow halls and corridors provided a distinct energy system. Also, its construction depended on materials that did not affect the environment and were highly durable. Therefore, sustainability concepts were applied 792 years ago in Islamic architecture. Nowadays, designers could learn more from those architectures and their construction methods to reduce the negative impact of recent construction strategies on the environment and human life. Sustainability concepts from the past can be adapted to modern designs. It sounds like a modern school design implementation of these principles was successful.

Keywords:
Design; Environment; Islamic Architecture; Old Mustansiriya Madrasa; Sustainability

A. INTRODUCTION

The concept of sustainability cannot be defined precisely and clearly because it depends on the researcher's vision of the topic he addresses. Therefore, there are several definitions developed for the term, attempting to reach a meaning that covers the field of study or knowledge related to the subject. Generally, sustainability may refer to a set of criteria, such as social-ecological measures, to direct human actions or products. Furthermore, it may represent a vision of the convergence of environmental, social, and economic purposes as well as expectations, aims, or goals of a system [1].

The term sustainability may be applied to explain the integration of social-environmental criteria in human activities. These activities may involve products or operations that affect the relationship between humans and ecosystems. This relationship constitutes part of social-ecological systems and sustainability. From this perspective, it can be used for applying social-ecological criteria to the planning, designing, and functioning stages of particular reference systems [1].

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However, it can involve studying how natural systems function and how they provide everything the environment needs to remain balanced. It also recognizes that human civilization plays a role in sustaining the way of life, but humans must do so responsibly [2]. Unfortunately, history has shown many examples of civilizations that caused serious damage to their environment, which ultimately affected their survival. That describes the learning to live in harmony with the natural world and protect it from destruction and damage [3], [4].

The Research and Innovation International Council in Building and Construction (CIB) describes sustainable building as "the sustainable production, use, maintenance, demolition and reuse of buildings and constructions or their components" [5]. Therefore, sustainable construction includes the whole life cycle of a building. Sustainable construction can also be defined as "a holistic approach seeking to restore and preserve the balance between the natural and the constructed environments as well as create settlements that establish human dignity and promote economic equity" [6], [7].

Sustainable architecture is becoming increasingly prevalent as people become more aware of the effects of buildings on the environment. Architects aim to design structures to become more visually stunning and energy-efficient, using eco-friendly materials and technologies that reduce waste and carbon emissions [8], [9]. These buildings are also designed with the well-being of their occupants in mind, containing features such as natural light, ventilation, and green spaces [7]. Generally, sustainable architecture is a promising approach to designing buildings that meet both the needs of people and the planet. Sustainable architecture is significant as it aims to reduce the negative impact on the environment during the construction and operation of buildings [10]. Upon doing this, sustainability improves the quality of life for those who live and work in these buildings.

Sustainable architecture can be executed via several prime principles, which ensure that structures are environmentally friendly and resource-conscious and boost the health and well-being of their occupants [5], [11]. These principles include:

1. Energy Efficiency: A sustainable building's design minimizes energy consumption and incorporates renewable energy sources where possible. That concerns using passive design strategies, energy-efficient systems, and technologies that optimize the building's performance [11].
2. Resource Conservation: Sustainable architecture emphasizes the reliable use of resources, such as water, materials, and land. That can be achieved through efficient space planning, waste reduction, and recycled or renewable materials [5].
3. Eco-Friendly Substances: The materials for a sustainable building are essential. Sustainable architecture tends to use substances that have little environmental effect and are locally available, renewable, and non-toxic [7], [11].
4. Health and Well-Being of Occupants: A primary purpose of sustainable architecture is to enhance the life quality for the residents of the building. That can be conducted by confirming indoor air quality, access to natural light, and acoustic comfort and making spaces enable physical and mental well-being.
5. Adaptability and Soundness: Sustainable buildings are designed to be flexible and versatile to respond to changing necessities and needs over time. That includes assessing the building's lifecycle, its ability to withstand extreme weather options, and the potential for future changes.

Sustainability is not only related to the environment, but it also deals with the health of communities and ensures that people are not exposed to suffering due to environmental legislation, with the need to test the long-term effects of human actions. Therefore, sustainability can describe the integration of natural systems with human patterns to provide continuity [9]. However, sustainability consists of three parts. Those are environmental, social, and economic sustainability, as illustrated in Figure 1.

Figure 1. Constituents of sustainability (Edited by Authors from [11])

Sustainability is crucial in architecture to ensure the long-term well-being of the planet and the people who inhabit it. By carefully considering the ecological, economic, and social impact of the designs, it can create buildings and communities that are not only beautiful and functional but also sustainable and resilient [12]. It is important to remember that the architect is responsible for protecting the environment and promoting social equity; therefore, sustainable architecture is one way to do that.

Environmental sustainability is a vital concept emphasizing the significance of maintaining the balance between society and the environment. It highlights the need to use natural resources in a way that doesn't harm the environment and ensures that the needs of future generations are met. Development is essential, but it should not come at the cost of the environment. Therefore, it must sustainably exploit natural resources to ensure that the planet remains habitable for future generations [13].

Social sustainability enables the collective use of common areas to enhance human relations. It aims for social development that eliminates poverty and reduces inequality among populations [14].

Economic sustainability is the development of a productive and social economy in which skillful employment prevails. It is a society of equal opportunities and social cohesion, ensuring the maintenance of the environment and rational use of resources[15].

Building environmental and sustainable assessment methods are critical for promoting sustainability in building design and construction. By considering a life cycle approach, design and construction methods can benefit the building owners and occupants alike, including lower environmental impacts, improved indoor air quality, and reduced operational expenses over the long term. Some researchers and designers classify sustainable strategies for designing public buildings in general into six strategies [9], [16], as illustrated in Figure 2.

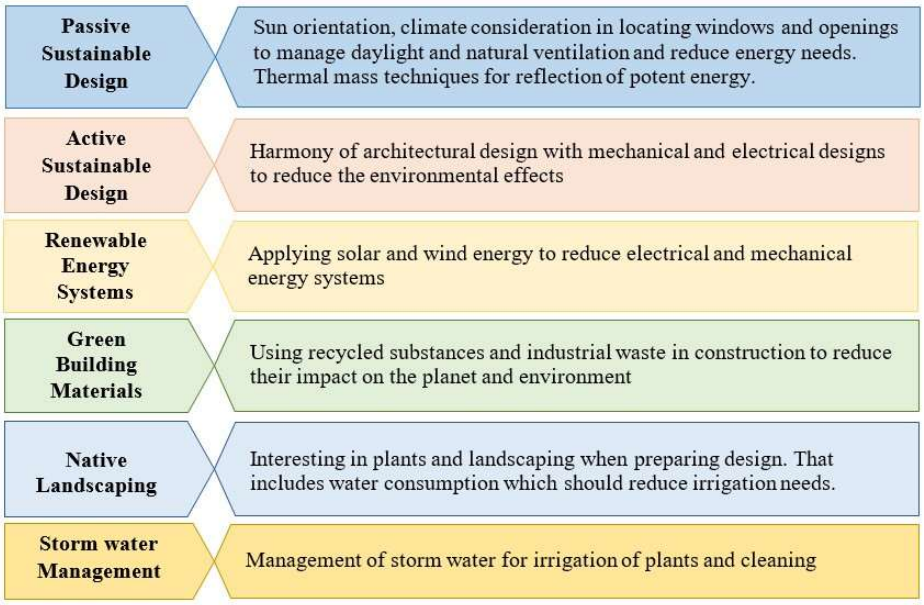

Figure 2. The six sustainable strategies for designing public buildings (Edited by Authors from [9], [16],)

There is an interesting observation; it is remarkable to think that sustainability has been a part of the design and construction of heritage buildings for so long. It is significant to discover what specific sustainable practices were used back then and take the learning from them to continue improving sustainability in modern-day construction. The concept of sustainability is not considered a new phrase. However, it represents a concept that has been embodied by Islamic architecture in various parts of the world since old times through spontaneous and experimental harmony linked to the environment and optimal exploitation of natural resources without affecting the environment [17]. The Islamic teachings include many principles of sustainability that are intertwined with social organization and human behavior, which were reflected in the urban aspect at the level of city planning and urban communities and at the level of Islamic architecture, which derived its concepts from the teachings of Islam [18].

The research issue boils down to the need for school buildings due to the significant shortage, in terms of numbers, in the country. It is required to prepare designs compatible with modernity, to achieve sustainability principles, and are linked to historical and spatial values. Therefore, this article focuses on a comparative study of sustainability applications used in an old school building in Baghdad, the Mustansiriya Madrasa (School), to extract concepts that can be used in designing modern sustainable school buildings. It is significant to describe how the designer can learn from the past to create a more sustainable future.

B. METHODS

The research was designed to study the concepts of sustainability applied in modern buildings and compare them with the design method implemented in the Mustansiriya School to derive sustainability ideas from the old design and use them in contemporary school designs. The research methodology included studying the principles of sustainability in its modern sense, analyzing the design of the Mustansiriya School to show the extent of compatibility between them, and applying these concepts in the design of a modern school.

C. RESULT AND DISCUSSION

A. ISLAMIC ARCHITECTURAL HERITAGE

In the recent, ever-changing world, it is challenging to cope with the needs of civilization. That is why it is significant to look back on the past and learn from it to continue to develop and improve. Therefore, it is crucial to find a balance between modernity and ethics, and the research can help to achieve these aspects by providing designers with a basis of principles to guide their work. It is also worth noting that ethics have played a significant role in the evolution of societies throughout history [19]. The world's architectural heritage of Arab has been embodied over time [20]. Despite the vast and various physical existence of that heritage, many architects still struggle to integrate it into the international language and culture of architecture. However, the conventional constructed conditions always have much to guide architects and designers in creating new aspects [21]. However, this heritage is uncertain to survive in the long term, but it is significant to continue learning about it. It is interesting how built spaces can convey information and have inherent societal rules [18]. That is not merely about the shapes and surfaces but also the codes and associations that people make with these spaces. Thus, it is essential to ensure that these principles are preserved for future generations.

Islamic Cities depended on the fact that they were built as inspired by the Holy Quran and the teachings of Islam. They were designed to address the challenges of modern urban culture while staying true to Islamic values and principles [12]. In addition to the physical environment, Islamic cities were built on ethical and social precepts, emphasizing community, sustainability, social justice, and economic and religious freedom. The result was a harmonious and prosperous society that values diversity and mutual respect [22]. A robust social system was at the heart of the Islamic city, bringing together neighborhood events and social issues to promote a strong sense of community and morality. These concepts were achieved through teaching and learning in the cities of the Islamic State in its various eras. Therefore, educational schools were built, which focused on teaching the sciences of the Quran, jurisprudence, and Hadith in addition to teaching other natural sciences. One of the most famous educational schools established during the Abbasid period was the Mustansiriya School (Old Mustansiriya Madrasa) [23], which is the subject of this research.

A.1. STRUCTURAL AND ENVIRONMENTAL TREATMENT IN OLD MUSTANSIRIYA MADRASA

The Mustansiriya Madrasa is a majestic structure situated in a location overlooking the Tigris River. It took six years to build from 1227 to 1233 AC and covers an area of 4,836 square meters. The complex was designed around a grand rectangular courtyard of 1710 square meters, which contained four iwans spanning across two floors [23], as illustrated in Figure 3. Each iwan was designated to a specific school of Islamic law, which presents incredible attention to detail in the architecture. The iwan is a covered courtyard protected from rain and sunlight. It is an open hall that is wide on one side and contains a basement. It was built to add size and beauty to the building and to provide a spacious, covered place that performs the function of a foyer in the palace. In the Mustansiriya Madrasa, students had access to various facilities such as a bathhouse, general hospital, pharmacy, food storage site, kitchen, library, teaching hall, and a mosque [22], [23]. The school also provided housing for the students, which included food, clothing, and a monthly salary. Additionally, there was a designated space for student housing. In general, Mustansiriya Madrasa was a medieval-era scholarly complex that provided a universal system of higher education. Various sciences were taught there, such as Medicine, Astronomy, Philosophy, and Mathematics, in addition to Islamic religious sciences [23].

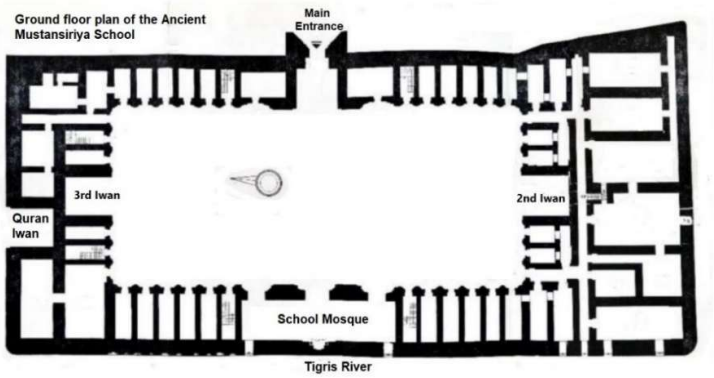

Figure 3. The ground floor of Mustansiriya Madrasa [23]

The historical architecture of Mustansiriya Madrasa was an outstanding example of the Islamic architectural development of the Round City of Old Baghdad.

The design of Mustansiriya Madrasa included different materials, textures, and patterns. The iwans and arched doorways were framed using simple vertical and horizontal brick lines, as shown in Figure 4. Various patterns were used, such as carved terracotta arabesques, concentric moldings with several shapes of stars and geometric polygons, masonry, and carved brickwork featuring different floral themes, reminiscent of earlier Abbasid decorations.

Its construction was supervised by the school's engineer, Muayyad al-Din Abu Talib Muhammad bin al-Alqami. When the building was completed, its opening was celebrated with a large ceremony, attended by the Caliph himself [23].

The building consisted of two stories. The ground floor included 40 halls, while the first floor included 36 halls (see Figure 3), which contained balconies overlooking the courtyard. The structural system used was the load-bearing wall system, which relied on thick brick walls to bear the weight of the roofs, which were also implemented with brick vaults.

Figure 4. Vertical and horizontal bricks used in building the Madrasa [Photo by Authors]

B. SUSTAINABILITY CONCEPTS IMPLEMENTED IN THE MUSTANSIRIYA MADRASA

Based on the design of the Mustansiriya School, it appears that the sustainability of the building is achieved, as illustrated in the following aspects:

1. The design pattern prepared by the designer, which adopted the rectangular shape, the central courtyard, and the towering height, provided a form for the sustainable design resulting from the extended areas for the facades, the orientation of openings to take benefits from daylight, and for ventilation, as illustrated in Figure 5.
2. The school location near the Tigris River provided it with cooling and filtering of the air when it passes through the river and the trees on the banks of the river, see Figure 6.
3. Using thick brick walls during the construction provided a thermal mass technique. Thick walls can absorb heat from the sun during the day and release it into the building at night to benefit from solar energy. That can be classified as an active, sustainable design.
4. Skylights in the narrow halls and corridors allowed cooling, heating, and natural lighting, which represented a good harness of solar and wind as a renewable energy system, see Figure 7.
5. Double-height ceilings provided better ventilation and additional lighting and an enhanced feeling of spaciousness, which is considered an active, sustainable design.
6. Using bricks inside and outside the building did not require maintenance and saved energy. It also absorbs external noise and protects against fire, wind, and hail. Using bricks in construction is regarded as a green building material. Clay bricks have a lower “thermal conductivity” ranging between 0.5-1.0 Watts/meter-Kelvin. The substance's thermal conductivity directly relates to its capability to transmit heat effectively. Low “thermal conductivity” materials, like clay-brick, are considered thermal insulators as they limit the heat motion through them. The thermal feature is particularly sensual, regarding the buildings, since it supplies indoor regulation of heat by preventing cold or hot air from penetrating inside and stopping them from running into the surrounding circumstances during summer or winter.
7. The balconies extended along the courtyard provided an additional source of ventilation and natural light [24], see Figure 8.
8. Skylights and high ceilings have provided long-term sustainability, see Figure 9. The plant in the interior courtyard of the school space provided plant cover for cooling and improving the air, which is described as native landscaping.

Most sustainable concepts were taken into consideration during the design and construction of the Mustansiriya Madrasa to reduce the negative impacts on the natural environment and climate.

Figure 5. A rectangular shape with a central courtyard and towering height for sustainable design (Source: Google Earth)

Figure 6. The location of Mustansiriya Madrasa (Source: Google Earth)

Figure 7. Narrow corridors in the Mustansiriya Madrasa [23]

Figure 8. The balconies extended along the courtyard [23]

Figure 9. The skylight in the Mustansiriya Madrasa [23]

C. A CASE STUDY OF DESIGNING A MODERN SCHOOL MODEL

C. 1. PROJECT DEFINITION

The project aims to design a sustainable school to meet the requirements of third-year students in the architectural engineering department. The main goal is to create an academic environment that stimulates creativity and innovation in line with modern educational concepts. The steps of the design are illustrated in Table 1.

Table 1. Steps of designing a sustainable school project

Item	Description
Design Principles:	Students are asked to employ the latest architectural technologies and sustainable innovations to ensure the achievement of the specified goals. The design should focus on creating a sustainable educational environment that fosters creative thinking and contributes to developing a sustainable academic community.
Functional program	Designing a school with 18 classrooms, each accommodating 25 students. Plan six laboratories with modern scientific equipment. Design an architectural blueprint for an advanced library catering to diverse educational needs. Develop a meeting hall equipped for various functions and workshops. Design an administrative plan with offices for management and supervisors. Plan a multipurpose hall with a capacity of 120 people for events and conferences.
External Facilities	Plan and design a cafeteria providing healthy meals for students and staff. Design the main sports field to encourage physical activity. Create a main gathering area for students to enhance social interaction
Sustainable Design Concept	Integrate solar energy systems and LED lighting for enhanced energy efficiency. Incorporate eco-friendly and recyclable building materials in the design. Develop an effective waste management and recycling system within the school premises. Design green spaces and gardens to improve air quality and overall well-being.
Safety and Accessibility	Integrate an advanced security system to ensure the safety of students and staff. Design accessible pathways and entrances to cater to individuals with special needs.
Innovation and Design	Encourage innovative design solutions and the optimal utilization of spaces. Design collaborative workspaces and workshops to promote creative thinking. Prepare an accurate budget for the construction and implementation of amenities

The design program was scheduled to guide the students through four essential phases of designing a sustainable school. It emphasized creativity, sustainability, and collaboration while leveraging the innovative solutions for Mustansiriya Madrasa. The four phases are described in Table 2.

Table 2. The four phases of the work program for sustainable school design

Stage	Period	Description
Conceptualization and Research Studies	2 weeks	Research modern educational concepts and emerging trends. Explore the innovative solutions of the Mustansiriya Madrasa for creative insights. Identify sustainable architectural technologies and innovations. Understand the specific needs of the students and align them with modern educational principles. Establish the conceptual foundation for sustainable school design
Preliminary Design	4 weeks	Develop initial sketches and 3D models for the school of 18 classrooms, considering creative and sustainable elements
Detailed Design and Integration	5 weeks	Finalize detailed architectural drawings for classrooms, laboratories, a library, meeting halls, an administrative wing, and a multipurpose hall. Integrate solar energy systems and LED lighting for enhanced energy efficiency.

		Incorporate eco-friendly and recyclable building materials into the detailed design. Develop an effective waste management and recycling system within the school premises. Design green spaces and gardens to improve air quality and overall well-being. Implement security features and accessible pathways to ensure safety and inclusivity. Enhance the design with innovative solutions inspired by Al-Mustansiriya School. Verify the compatibility of the design with the functional program and sustainability goals.
Finalization and Presentation	4 weeks	Refining the design based on feedback and evaluations. Developing a comprehensive budget for construction and amenities. Preparing a detailed implementation plan, including phased construction. Conducting a final presentation to stakeholders, emphasizing sustainability and creative elements. Obtaining necessary approvals and feedback for any final modifications. Ensure alignment with the vision of Al-Mustansiriya School and leverage their creative solutions. Document the final design, including all architectural and structural drawings and specifications.

To ensure that the sustainability aspects inspired by the Mustansiriya Madrasa are incorporated into the design of the new school, the following steps can be considered;

1. Rectangular Shape and Central Courtyard;
2. Proximity to Natural Elements;
3. Thermal Mass Technique;
4. The implementation of passive sustainable design strategy to enhance energy efficiency;
5. Skylights in Narrow Halls and Corridors;
6. The application of active sustainable design principle to enhance the overall environmental performance;
7. Skylights and High Ceilings;
8. Interior Courtyard Planting;
9. Selection of native plants that are well-suited to the local climate and contribute to the sustainability of the school environment.
10. Sustainability Considerations

C. 2. A COMPARATIVE OF MODERN DESIGN WITH THE MUSTANSIRIYA DESIGN

A design has been prepared for a modern school that considers aspects of sustainability. The design idea is derived from the Mustansiriya Madrasa (See Figures 10 and 11). The same facades were adopted, and a rectangular shape with a central courtyard was chosen for the concept since the rectangular shape provides facade spaces on the front and back sides of the building. It gives space to increase daylight and ventilation, and reduce the dependence on the generated energy. The modern design of the school consists of three stories. It has 18 classrooms, six laboratories, a doctor's room, three cafeterias, two exhibitions, two ceremony halls, a main hall, and the administrative building, as illustrated in Figure 12.

The proposed sustainable structures should be designed for the corresponding environmental requirements and climate to be truly energy efficient. The proposed structural system consists of reinforced concrete columns, beams, and slabs. These structural elements do not consume large amounts of construction materials. However, the recommendation is to use industrial wastes to replace a percentage of cement in concrete mixtures, such as silica fume and blast furnace slag, to reduce cement consumption, which, in turn, minimizes carbon dioxide emission and enhances sustainability [25]. Therefore, the compatibility between architectural and structural design contributes to improving sustainability, and the design of modern schools has adopted this approach.

On the other hand, the six previously mentioned strategies were taken into account in preparing the design of the modern school. It included the direction of the sun and its effects, and the benefits of solar and wind to reduce the electrical energy system, especially since the climate in Iraq is hot in most of the months of the year in which schools are in session. Additional structures were made; they provide shade from the sun's rays but do not block the light (see Figure 13). Long-term cost savings due to reduced energy and water consumption lead to lower utility bills. Also, earth storage tanks were designed to collect rainwater that will be used for gardening and cleaning. Maintenance costs decreased, and the durability increased as a sustainable building was designed to last longer and require fewer repairs and replacements. Healthier indoor environments resulted from improved air quality, access to natural light, and better acoustics enhance occupant health, well-being, and productivity, which were achieved through large areas of shaded windows and towering heights of the building. The design relied on the sustainable concepts implemented in Mustansiriya Madrasa.

The design methodology of the modern school and Mustansiriya Madrasa was inspired by establishing a relationship with local communities since local expertise provided design solutions that used local skills and

materials to be compatible with the local climate, culture, and community. Therefore, both buildings were designed to respond to the local climate with long walls placed between East and West to maximize shade and large openings in perpendicular directions to bring wind and light deep into the classrooms. The walls were constructed by local bricks and materials.

Figure 10. The similarity of facades in the Mustansiriya Madrasa and the modern school building.

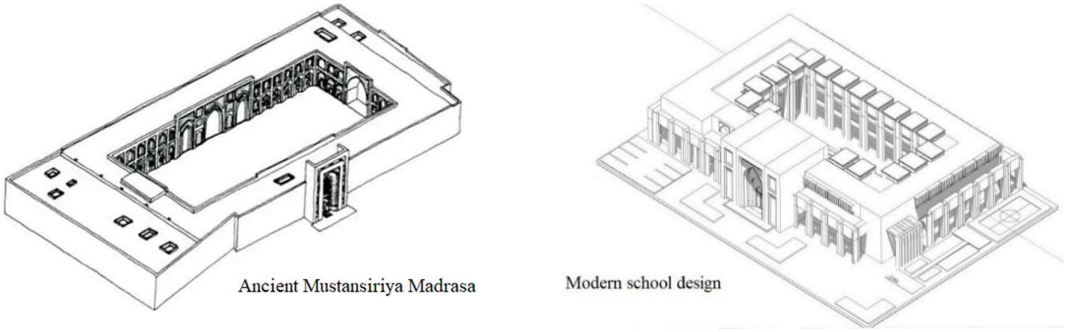

Figure 11. The same concept of the design for the modern building

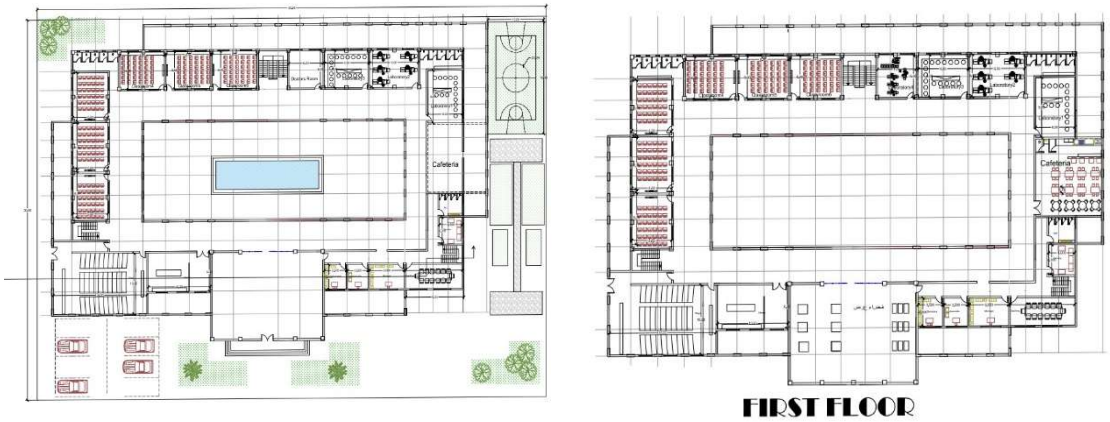

Figure 12. First and second stories of the modern design of the school

Figure 13. The modern sustainable school

D. CONCLUSION

This research paper describes the sustainable features of the Old Mustansiriya Madrasa, a school building constructed during the thirteenth century AD in Baghdad. The following conclusions can be derived. Sustainability concepts were applied in architecture over 790 years ago in Baghdad, the capital of the Islamic state. Also, the sustainability of architecture depends on several basic principles, including energy efficiency, conservation of natural resources, use of environmentally friendly materials, and a design style that provides sustainability. Many Islamic buildings included multiple principles of sustainability that are interlaced with social regulation and human behavior. These architectures were provisioned in the urban aspect at the level of city planning, urban communities, and Islamic architecture level. The design of Mustansiriya Madrasa incorporated various sustainable features, a rectangular shape with a central hollow courtyard to improve natural ventilation and lighting is an example. Thick brick walls provide thermal mass techniques for solar energy, and skylights in narrow halls and corridors supply a renewable energy system. The location of the Madrasa on the Tigris River bank and landscaping inside and near the building also provided natural cooling, air ventilation, and filtering.

Nowadays, architects and designers can learn from these old sustainable architectures and construction methods to reduce the negative impact of recent construction strategies on the environment and human life. Adopting sustainable design principles, combining inventive technologies, and memorizing the successes of pioneering sustainable tasks can help industry experts create a built environment that truly reflects the values of a more sustainable, honest, and resilient future.

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