Mansoura University
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IMPLEMENTATION OF SUSTAINABILITY PRINCIPLES IN ISLAMIC ARCHITECTURE: AN ANALYTICAL STUDY IN LIGHT OF THE GREEN PYRAMID RATING SYSTEM STANDARDS

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RESEARCH JOURNAL OF THE FACULTY OF TOURISM AND HOTELS
MANSOURA UNIVERSITY
ISSUE NO. 14, DECEMBER. 2023

تطبيق مبادئ الاستدامة في العمارة الإسلامية: دراسة تحليلية في ضوء معايير نظام تقييم الهرم الأخضر

ملخص البحث

يعد مصطلح "الاستدامة" من المصطلحات الهامة التي برزت مؤخرا في مجال التصميم البيئي والمعماري، ومن المثير للاهتمام أنه بمجرد دراستنا لذلك المصطلح وغيره من المفاهيم المرتبطة به مثل " العمارة المستدامة" أو " العمارة الخضراء" أو " التصميم المستدام" سنكتشف على الفور أنها ليست حديثة بل كانت مطبقة منذ قديم الأزل في مجال الهندسة المعمارية، فعلى سبيل المثال يعتمد مفهوم "العمارة المستدامة" على بعض المبادئ المحورية والتي بدورها تساهم بقدر كبير في تلبية احتياجات الأجيال المتعاقبة، وتتمثل تلك المبادئ في الحفاظ على التراث الثقافي، وإنشاء مستوطنات بشرية صحية، وحماية البيئة المحيطة، وتجدر الإشارة الى أن مبادئ الاستدامة سالفة الذكر قد تم تطبيقها بدرجة كبيرة في العمارة الإسلامية والتي ركزت بشكل أساسي على تحقيق التوازن البيئي والاجتماعي والاقتصادي والثقافي في المجتمع. وعلى نحو آخر فقد شهدت العقود القليلة الماضية ظهور بعض النظم البيئية التي تتضمن بعض المتطلبات والمعايير

لتحقيق قضايا العمارة البيئية، ومن هذه الأنظمة نظام تقييم الهرم الأخضر، وهو نظام تقييم مصري يهدف إلى تحقيق البعد المستدام للمباني بالإضافة الى مساعدة المهندسين المعماريين في انشاء مجتمعات مستدامة. ويعتمد هذا النظام على سبع معايير أو محددات رئيسية، هي: الموقع المستدام، كفاءة الطاقة، كفاءة استخدام المياه، الموارد ومواد البناء، جودة البيئة الداخلية، الإدارة، وأخيرا الابتكار في التصميم. وبناءا على ذلك يمكن تحديد أهداف هذا البحث في القاء الضوء على تطبيق مبادئ الاستدامة في العمارة الإسلامية، بالإضافة الى دراسة مدى التوافق بين مبادئ الاستدامة في العمارة الإسلامية وبين معايير نظام تقييم الهرم الأخضر المصري.

الكلمات الدالة: الاستدامة، العمارة المستدامة، نظام تقييم الهرم الأخضر، العمارة الإسلامية.

Implementation of Sustainability Principles in Islamic Architecture: An Analytical Study in Light of The Green Pyramid Rating System Standards

Abstract

Lately, various modern notions in the field of architectural and environmental design have appeared, such as sustainability, green architecture, sustainable design, and so on. Intriguingly, when we examine these notions, we discover that they are not modern, but they have always existed in architecture since ancient ages. For instance, sustainable architecture depends on some focal principles such as maintaining cultural heritage, establishing healthy human settlements, and protecting the environment, all of which help successive generations meet their needs. We can notice that the previous principles were implemented in Islamic architecture, which mainly focused on maintaining environmental, social, economic, and cultural balance. The last few decades have witnessed the rise of some ecological systems that include some requirements and standards to codify the issues of environmental architecture. Among these systems is the Green Pyramid Rating System (GPRS), which is an Egyptian rating method aimed at assessing the sustainable dimension of buildings as well as helping architects forms sustainable communities. This system is mainly based on seven standards: sustainable site, energy efficiency, water usage efficiency, materials, indoor environmental quality, management, and innovation. So, the main objective of this research is to prove the effective

application of sustainability in Islamic architecture as well as to examine the amount of compatibility between principles of sustainability in Islamic architecture with the standards and requirements of the Green Pyramid Rating System (GPRS).

Key words: Sustainability, sustainable architecture, Green Pyramid Rating System (GPRS), Islamic architecture.

The concept of Sustainability

Sustainability is considered one of the most famous concepts that has arisen lately, and it is defined by the United Nations Brundtland Commission as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". As a result of the growing threat posed by climate change today, the concept of sustainability has become a very important and necessary solution for nearly 140 developing nations to meet their development needs by taking significant steps to guarantee that progress today does not have an adverse effect on future generations [1].

Recently, sustainability has become a very familiar concept in the field of architecture, and it has some significant terms that emerged from it, such as sustainable architecture, sustainable design, and so on.

Sustainable Architecture.

It is the architecture that aims to reduce the detrimental effects that buildings have on the environment by using resources more wisely and with more efficiency, including less energy, less material, less development space, and the ecosystem as a whole [2].

1 https://www.un.org/en/academic-impact/sustainability, accessed on: 15/9/2023.

2 For More Reading, See:

Bielek, B. (2016). Green Building – Towards Sustainable Architecture. Applied Mechanics and Materials, p. 824, 751–760. Available at: https://doi.org/10.4028/www.scientific.net/amm.824.751, accessed on: 20/9/2023.

Sustainable architecture has a number of principles, which are considered ideas and solutions that are proposed to solve problems resulting from environmental misuse in terms of environmental pollution, lack and depletion of natural resources, etc. These principles are summarized as follows:

1- Energy conservation:

Buildings must be designed in a way that reduces the need for fossil fuels and relies on natural sources of renewable energy (solar energy, wind energy, etc.). This idea has been presented since man chose caves for housing and shelter, as he inhabited caves facing the south to receive sunlight instead of the north in areas with moderate climates. Among the ways to reduce energy consumption are also the use of building materials available on site instead of consuming energy in transportation operations, the use of construction materials with long-term resistance to increase their lifespan during the construction process, and reliance on the design and implementation process. It is based on scientific methods that reduce the need for fuel and rely on natural sources of energy [1].

2- Sustainable site:

This principle depends on erecting the building on the site in a way that respects the site and does not cause fundamental changes to the site of the building, so that if the building is removed, the site returns to its previous condition before it was built on it. Among the most

[1] غادة أمين رمضان وآخرون، (2021)، الاستدامة في العمارة المصرية القديمة، مجلة العمارة والفنون والعلوم الإنسانية، عدد خاص، ص ١٢٢٤.

important examples that express respect for the site are the Bedouin tents. It is made from camel and sheep hair and is fastened with only some wooden pegs and ropes. When the Bedouins leave the place, we notice that there are no fundamental changes to the site. Perhaps their residence in the place is inferred only from the remains of the ashes of the fire that they lit for cooking or heating [1].

3- Climate Adaption:

The problem of climate control and creating a climate suitable for human life is a problem that man has sought to solve since the beginning of humanity. Man was keen to ensure that his dwelling included two main elements: protection from the climate and creating an internal atmosphere suitable for his comfort. Dwelling in icy areas is designed with an external configuration and an internal space that helps to live in a place with an elevation at which hot air collects for heating. In hot regions, we find dwellings with an inner courtyard that stores cold air at night to combat the intense heat during the day. In tropical regions, the formation of the dwelling's mass facilitates the movement of air through it to help get rid of humidity. Hence, we see that the design and formation of buildings throughout history were a reflection of the high solutions that increased the feeling of heat and were different and appropriate for each time period and place to achieve this goal. Therefore, the principle of climate adaptation is

[1] غادة أمين رمضان وآخرون، (2021)، الاستدامة في العمارة المصرية القديمة، ص ١٢٢٤.

considered one of the most important principles of architecture [1].

4- Users respecting:

Sustainable architecture prioritizes human safety and environmental preservation, focusing on reducing dangerous work and injuries in the construction industry. It emphasizes quality construction processes, scientific methodologies, and environmental disaster mitigation. Buildings should be designed for their functional purpose, considering individual privacy and needs, and ensuring materials have a harmless effect on workers and users [2].

5- New Recourses consumption Rationalizing:

This principle aims to reduce resource use by designing buildings to serve as resources for future generations, reducing the need for new resources and promoting recycling and reuse of building materials, rather than demolition[3].

[1] مها صباح سلمان الزبيدي، بهجت رشاد شاهين، (٢٠٠٨)، مبادى الاستدامة في العمارة التقليدية وفق المنظور الإسلامي، المجلة العراقية للهندسة المعمارية، الجامعة التكنولوجية قسم الهندسة المعمارية، العراق، ص ٨٤-٨٥.

[2] منى عبد السلام الشماس، (٢٠٢١)، الاستدامة في العمارة السكنية على مستوى التصميم الداخلي، مجلة كلية الفنون والإعلام، جامعة مصراته، ص ١٨.

[3] سامي بدر الدين سراج الدين، (٢٠٠٨)، مدخل لتصميم المباني السكنية وفقا لمفهوم العمارة: الاستدامة والتوافق البيئي للتجمعات العمرانية، المؤتمر العربي السابع للإدارة البيئية: نمو التجمعات السكانية ومشروعات التنمية وآثارها على البصمة الأيكولوجية للمدن العربية، المنظمة العربية للتنمية الإدارية، القاهرة، ص ٩٣-٩٤.

6- Waste management:

Construction operations generate significant waste, accounting for 30% of total waste. This includes construction stage waste, materials, glass, and paper. The waste management process aims to reduce violations, reuse, recycle, and dispose of waste responsibly [1].

Green Pyramid Rating System (GPRS).

The Green Pyramid Rating System (GPRS) is a system for evaluating sustainable buildings in Egypt. It is a local environmental system that was formulated by the Egyptian Green Building Council (EGBC) with the participation of the National Center for Housing and Building Research (HBRC) in 2010. The first version of this system was released in April 2011. The building evaluation is part of this system. Through two stages: the design stage and the post-construction stage, provided that it undergoes evaluation during the design stage [2]. This system is based on seven main standards or categories, which are represented in: (1) sustainable site, (2) energy efficiency, (3) water usage efficiency, (4) materials, (5) indoor

[1] غادة أمين رمضان وآخرون، (2021)، الاستدامة في العمارة المصرية القديمة، 1226.

[2] أمل محمد ابراهيم طه وآخرون، (٢٠١٤)، دراسة تحليليه لتقييم نظام الهرم الاخضر، مجله العلوم الهندسية، كليه الهندسة جامعه اسيوط، المجلد ٤٢، ص ١٠٥٦.؛ أسامة عبد النبي قنبر، أحمد علاء لبدة، (٢٠١٩)، معايير التصميم الداخلي المستدام في ضوء نظام تقييم الهرم الأخضر، "مجلة البحوث الهندسية، العدد الرابع، ٤٨-٦٠"، ص ٤٩.

environmental quality, (6) management, and (7) innovation[1].

It must be mentioned that the primary goal of the Green Pyramid Rating System is to assist sustainable development in Egypt. Besides, it has some other important objectives[2] that can be represented in:

- Providing a good practice standard that helps evaluate buildings through a transparent and credible environmental classification and producing specific national evaluation standards and regulations.
- Offering a source that details the environmental requirements that Egyptian construction must meet.
- Reducing the negative impact of buildings on the environment and promoting creative approaches that mitigate them.
- Using natural resources to guarantee the protection of the strategic reserve and the distinctiveness of the Egyptian landscape.
- Facilitating educated conversation with all interested parties and assisting in the creation of sustainable buildings
- Encouraging the building designers to take the environment into account and to recognize the need for sustainable construction approaches.

[1] Abd El-Hafeez, (Mostafa Mohamed) et al, (2014), Adapting the Green Pyramid Rating System for Assessing Zero Energy Concept on Neighborhoods Level, "Port Said Engineering Research Journal Faculty of Engineering - Port Said University, vol. 18 (1), 153-160", p. 153.

[٢] أسامه عبد النبي قنبر، أحمد علاء احمد لبده، معايير التصميم الداخلي المستدام في ضوء نظام تقييم الهرم الاخضر، ص ٥٠.

Principles of sustainability in Islamic Architecture and its conformity with standards of The Green Pyramid Rating System (GPRS)

Islamic architecture could be classified as a sustainable architecture, because the Muslim architect paid great attention to apply the principles of sustainability in architecture by introducing some solutions and architectural treatments that agreed with the basics of "green architecture" or "sustainable architecture"[1]. He also succeeded in mixing the dimensions of social, cultural, and economic sustainability with environmental requirements[2]. Thus, we can notice that there is a great compatibility between principles of Islamic architecture and categories or dimensions of the environmental rating systems that have emerged lately. Therefore, the following part of this research will show evidence of the similarity between the principles of sustainability in Islamic architecture and the standards of the Green Pyramid Rating System (GPRS).

1. The Sustainable Site

The Sustainable Site is considered one of the most important standards of the Green Pyramid Rating System

[1] شرين عبد القادر محمد الفيومي، (٢٠١٥)، توظيف مبادئ الاستدامة في العمارة الإسلامية لمواجهة التحديات المعمارية رؤية خزفية، "مجلة التصميم الدولية، المجلد ٥، العدد ٣، ص ص ١٢٥٧-١٢٦٦"، ص ١٢٥٩.

[2] Edwards, Brian, & Chrisnad, du Plessis, (2001), Snakes in Utopia: A brief history of sustainability, in "Architectural design'; vol. 71; No. 4, Luglio", p. 21.

(GPRS) [1], which is based on four main requirements: (a) the site selection, (b) reducing the effect of the sun's heat, (c) increasing the open areas, and (d) reducing light pollution. This standard with its requirements matches the principles of Islamic architecture [2]. The following points will highlight the means that both the founders and Muslim architects utilized to achieve the requirements of a sustainable site in their buildings:

(a) The site selection

During the Islamic era, the founders paid great attention to choosing a distinguished site for their buildings in Cairo, which helped finally keep this site sustainable. Most of the Islamic architectural buildings are distributed in many famous and important streets and areas, such as *al-Mu□ iz Ldīn-Allah* Street, *al-Gamāliya, al-Sirūjiya, al-Miġarblīn, al-Ḥayāmiya, al-Darb al-Aḥmar, Bab al-Wazīr, al-Ṣalība*, the citadel's square, and so on. We can notice that all the previous places are concentrated in *al-Mu□ iz*Street with its surroundings and extensions, as well as the citadel with its surroundings [3]. This is because al-Mu'iz Street has a great historical and religious significance for Egyptians starting from the Fatimid era, while the citadel earned its

[1] ريهام محمد عيد وآخرون، (٢٠١٩)، دراسة تحليلية لنظام تصنيف الهرم الأخضر المصري وفقا لعناصر الاستدامة البيئية والاقتصادية والاجتماعية والثقافية، "مجلة جامعة أسيوط للبحوث البيئية، المجلد ٢٢، العدد ٢، ١١٩- ١٢٩"، ص ١٢١.

[2] وليد محمد الغمري وآخرون، (٢٠١٨)، دراسة مقارنة بين معايير الليد (LEED) ومبادئ الاستدامة في العمارة الإسلامية، "مجلة العمارة والفنون والعلوم الإنسانية، العدد ١٠ (١)، ٧٨٦- ٨٠٢"، ص ٧٨٧.

[3] ياسر اسماعيل عبد السلام صالح، (٢٠٠١)، العوامل المؤثرة على مخططات العمائر الدينية العثمانية في القاهرة والوجه البحري، (رسالة ماجستير، كلية الآثار، جامعة القاهرة)، ص ٣٤.

importance from being the center of rule and authority in Egypt for a very long time during the Islamic era.
It must be mentioned that the founders and architects selected the previous sites to facilitate the accessibility of their buildings by having them constructed within the public streets and neighborhoods.

(b) Reducing the Effect of the Sun's Heat

The Muslim architect put into consideration choosing a suitable place for the building that is distinguished by pure air and a moderate climate. In addition, he made a number of architectural treatments that helped in providing shade for the building and protecting it from the sun's rays, as well as increasing the ventilation inside it [1]. These treatments are represented in:

- using various shading and roofing methods such as domes, sheds, and different vaults, as well as daylight control in innovative ways.
- Constructing the buildings and their architectural units with different heights, which, side by side with the narrow lanes and winding streets, contributed to providing shade and decreasing the temperature degree.
- The usage of friendly environmental materials that reduced the effect of the sun's heat and created a

[1] يحيي وزيري. (١٩٨٧)، العمارة الإسلامية نظرة عصرية، "مجلة عالم البناء، العدد ٨١"؛ عماد محمد أحمد عجوة. (٢٠٠٩)، الحلول المعمارية المعالجة للظواهر المناخية بعمارة القاهرة منذ نشأتها حتى نهاية العصر العثماني، (رسالة دكتوراه، كلية الآثار، جامعة القاهرة)، ص ٥٠٢-٥٠٣.

thermal insulation [1], such as using mud brick and stone as building materials, as well as marble panels in covering the lower parts of walls, and finally roofing the buildings with flat wooden ceilings.

- Determining the direction of the building's plan in a specific way helped in reducing the effect of the sun's heat on the facades and other inner parts and architectural units of the building. This was one of the reasons for the irregularity and curvedness that appeared on most facades of Islamic architectural buildings [2].

(c) Increasing the Open Areas

The Muslim architect employed a variety of ventilation techniques in his constructions, such as:

- The courtyard "Saḥn" (pl. 1, 2, 3), which usually existed in the middle of the building, is employed to decrease the temperature in the summer by distributing the cold air to other inner parts of the building. Besides, the court usually contains a fountain that helps in providing fresh air and moderating the weather of the place[3].

[1] Siani, S. B. (1980), Buildings in Hot Dry Climates, John Wiley & sons, UK., p. 76.

[٢] ثروت عكاشة، (١٩٩٤)، القيم الجمالية في العمارة الإسلامية، دار الشروق، القاهرة، ص ٦٤.

[٣] عبد المسيح يوسف عشى، (١٩٩٥)، الأفنية الداخلية في العمارة العربية السكنية، (رسالة ماجستير، كلية الهندسة، جامعة القاهرة)، ص ١١٤-١١٥.

- skylight, whose place was carefully chosen to save efficient air and light for the building [1].
- windows of various shapes whose function differed from one architectural building to another. The architect distributed these windows carefully in the building, taking into consideration the climatic and social factors as well as the architectural requirements. For example, he used windows with narrow openings called "*Mašrabiya*" (pl. 4) in houses and other civil buildings and placed them on a protruding level of the building's façade in order to preserve the sanctity of the home [2]. On the other hand, the architect utilized different kinds of windows in the religious buildings that were characterized by their large size, depth, and wideness (pl. 5). This form of window is suitable for its function as a means of lighting and ventilation for the inner Iwans and parts of the religious building. Whereas he used a different shape of windows in *Sabils* that was compatible with their function as buildings for providing water for the passersby. The Sabil window is usually formed as a large metal grill window and wasn't placed inside a recess to facilitate the drinking process [3] (pl. 6).

١كمال الدين سامح، (١٩٨٧)، العمارة الإسلامية في مصر، الهيئة المصرية العامة للكتاب، القاهرة، ص ١٤.؛ شفق العوضي؛ محمد عبد الله سراج، (١٩٨٩)، المناخ وعمارة المناطق الحارة، الطبعة الأولى، عالم الكتب، القاهرة، ص ١٥٣-١٥٤.

٢ مايسة محمود داوود، (١٩٨٥)، النوافذ وأساليب تغطيتها في عمائر سلاطين المماليك بمدينة القاهرة. دراسة معمارية وفنية، (رسالة دكتوراه، كلية الآثار، جامعة القاهرة)، ص ٢٠-٢١.؛ تامر فؤاد، (١٩٩٣)، الفتحات كعنصر تشكيلي حاكم في البيئة المشيدة، (رسالة ماجستير، كلية الهندسة، جامعة القاهرة)، ص ٢٢.

٣ياسر اسماعيل، العوامل المؤثرة على مخططات العمائر الدينية العثمانية، ص 38.

(d) Reducing Light Pollution

The Muslim architect was keen to provide his buildings with appropriate lighting, whether natural or manufactured, in addition to limiting the intensity of natural light resulting from sunlight and reducing its negative effects. This was achieved by utilizing friendly environmental lighting means that have a beautiful appearance, such as:

- glass lamps, which were lit by oil.
- Lighting openings, which were mostly placed in the upper parts of the walls or in the ceiling to let enough light enter the building.
- Windows with different forms and sizes such as: *Qamariya* (pl. 7), *Šamsiya* (pl. 8), *Qandliya* (pl. 9), and so on. These windows were made from decorated wooden shapes, metal grills, or stucco dovetailed with colored glass [1]. It can be noted that the architect put into consideration designing it to be narrow from inside and wide from outside, which helped in increasing the viewing angle and preventing the direct entry of the sun's rays [2].

2. Energy Efficiency

The second of the GPRS standards is energy efficiency. This standard totally agrees with the main principles of Islamic architecture, which aim at enhancing energy usage and reducing its negative effects. This was achieved by taking care of the shade's existence and good distribution of

[1] مايسة داوود، النوافذ وأساليب تغطيتها في عمائر سلاطين المماليك، ص ٧٤.

[2] محمد مصطفى نجيب، (1975)، مدرسة الأمير كبير قرقماس وملحقاتها. دراسة أثرية معمارية، (رسالة دكتوراه، كلية الآثار، جامعة القاهرة)، ص ٢٠-٢١.

it in all parts of the Islamic city and its ways, which helped in saving energy by more than 30%, so the shade is considered one of the main topics of energy conservation and efficiency [1]. The Muslim rulers and architects utilized a number of means that contributed to providing shade to the city and its buildings. These means are represented in:

- Founding narrow and winding streets and lanes that helped in reducing the areas exposed to the sun and keeping the cold air stagnated in the lower parts of these streets.
- Making the direction of most city streets and ways from north to south because it helped in reducing the time of exposing these streets and their buildings' facades to the sun's heat, as well as helping in receiving the northern wind that contributed to cooling the atmosphere.
- Controlling the buildings' height to fit with the streets' width, as well as using protruding wings and windows in the upper parts of these buildings to provide shading to various parts of the street.
- Roofing the streets and corridors of the city by using different methods such as wooden porticoes, cloth ceilings, and so on.

Besides, the different types of Islamic buildings contained some architectural elements such as courtyards (pl. 1,2,3), lighting openings "*Manwar*", and various kinds of windows

[1] وليد محمد الغمرى، دراسة مقارنة بين معايير الليد (LEED) و مبادئ الاستدامة في العمارة الإسلامية، ص ٧٩٧.

(pl. 4,5,6,7,8,9). These elements, along with the architectural treatments made by the Muslim architect, played a very important role in providing natural light throughout the day, which is considered one of the main factors in saving energy.

3. Water Usage Efficiency

One of the most significant standards of the GPRS is water use efficiency, which aims to regulate the use of water and its efficient distribution through several methods, as well as decrease water wastage and ensure good drainage of water. It's quite clear that these goals were achieved in Islamic architecture through many means, as follows:

First, the architect was keen to provide the different architectural establishments with wells that helped in saving sufficient pure groundwater for these establishments. The water was raised from these wells by the waterwheel to be gathered in basins and then distributed to the various portions of the building, such as fountains, baths, kitchens, and so on, via lead and pottery airtight pipes and canals. The documents of Waqf stated that these wells weren't found only in Islamic houses and other residential establishments but also in most religious buildings, especially during the Mamluk era [1]. Among these religious buildings, are: Madrasa of *al-Nāṣir Moḥammed Ibn Qalāwūn* in *al-Mu'iz* street, Madrasa of *al- Ẓahir Barqūq* in *al-Mu'iz* street, Mosque of *al-Mu'ayad Shiekh*, Madrasa of *al-Ashraf Birsbāy* in *al-Mu'iz* street and his complex at the

[1] محمد محمد أمين وليلى إبراهيم، (١٩٩٠)، المصطلحات الأثرية في الوثائق المملوكية، الجامعة الأمريكية بالقاهرة، القاهرة ص ٢٤-٢٦.

Mamluk Cemetery, complex of *al-Ashraf Īnāl* at the Mamluk Cemetery, complex of *al-Ashraf Qaitbāy* at the Mamluk Cemetery, Madrasa of *Qanībāy al-Rammāḥ* in *al-Nāṣiriya*, complex of *al-Ġūrī*, and complex of *al-Amir Qurqmās* at the Mamluk Cemetery.

Besides, the Muslim architect founded the Sabil (pl. 10, 11), which is considered one of the most significant means of providing water for the city's inhabitants. The Sabil is considered one of the most important types of Islamic architectural buildings that appeared in Egypt starting from the Mamluk era. It is mainly a beneficent establishment built with the purpose of serving potable water to passersby, so it is also considered a water establishment [1]. The architecture of a Sabil developed in Egypt during Mamluk and Ottoman times. It basically stored water in a large underground cistern, known as a *Ṣihrīj*, whose size differed according to the area of the Sabil. This cistern is topped by the Sabil room, which is square or rectangular in form and has large windows with metal grills in its facades, never exceeding three in number. On the edge of the window, there was a water basin with a metal board on the external part for placing water cups. *Sabils* of this sort had either

[1] Lamei (Salih), (1989), The Cairene Sabil. Form and Meaning, in "Muqarnas, Vol.6, edited by: Oleg Grabar & Leiden E.J. Brill"., P.34.;
حسني محمد نويصر، (١٩٧٠)، مجموعة سبل السلطان قايتباى بالقاهرة. دراسة معمارية أثرية، (رسالة ماجستير، كلية الآداب، جامعة القاهرة)، ص ١ - ٥.؛ محمود حامد الحسيني، (١٩٨٨)، الأسبلة العثمانية بمدينة القاهرة (١٥١٧-١٧٩٨) مكتبة مدبولي، القاهرة، ص ٩.؛ محمد هاشم إسماعيل طربوش، (١٩٩٥). أسبلة القرن التاسع العشر الباقية بمدينة القاهرة. دراسة أثرية فنيه، (رسالة ماجستير، كلية الآداب بسوهاج، جامعة جنوب الوادي)، ص٤٦.

one window, two windows, or three windows. In front of each window from outside, there is another basin placed on the ground of the street for serving water to animals.

The founders and owners were keen to maintain the continuity of the Sabil's function, so they assigned an employee who was responsible for regulating the drinking or watering process and preventing water wastage. This employee is called "*al-Mizamlāty*", and he must have some special requirements to be suitable for this job, such as a healthy body and good morals, as it's mentioned in the documents of Waqf [1].

Secondly, the Muslim rulers and architects put into consideration how to ensure the good drainage of water. This was accomplished by establishing an accurate water drainage system in the different architectural buildings. In addition, these buildings include a gutter (*Mizrāb*), which is an essential architectural element used particularly in the drainage of rainwater collected over the roof of the building. The gutter is a pipe or duct that is usually made of metal or stone. It is placed over the rooftop in a sloping way and protrudes from the building façade [2]. The gutters drain the water into canals that were dug on the two sides of the streets and lanes because Islamic laws and legislations prevented the drop of water from gutters on these streets

[1] عبد اللطيف إبراهيم، (١٩٥٦)، وثيقة قراقجا الحسني، "مجلة كلية الآداب، جامعة القاهرة، المجلد ١٨، الجزء الثاني)، ص٢٤٢.؛ حسن الباشا، (١٩٦٦)، الفنون الإسلامية والوظائف على الآثار العربية، القاهرة، جـ ٣، ص ١٠٨٠.

[2] عبد الرحيم غالب، (١٩٨٨)، موسوعة العمارة الإسلامية، الطبعة الأولى، جروس برس، بيروت، ص٤١٣.؛ عاصم محمد رزق، (٢٠٠٠)، معجم مصطلحات العمارة والفنون الإسلامية، مكتبة مدبولي، القاهرة، ص ٣٠٦.

and lanes. Finally, the drain water is running in these canals to be collected in courtyards that were specially established for this purpose. It must be mentioned that the Muslim architect was keen to show these gutters in a very beautiful way by well designing and ornamenting them.

The documents of waqf stated that the gutter is found in a different place inside the Sabil, as it is placed on the ground of the *Sabil* room directly in front of the *Šādrwān* or the *Salsabīl* to drain its water [1].

4. Materials

The fourth of the GPRS standards is materials and resources, which is mainly based on some requirements, such as the use of regionally procured and friendly environmental materials, as well as reducing the negative effects of these materials and achieving the major benefit of them throughout using innovative construction methods [2].

We can notice that the Muslim architect was a pioneer in applying these requirements by using suitable materials for establishing his architectural buildings with their units and elements, as follows:

- He used local and regionally procured materials that already existed in the Egyptian environment, such as mud brick, stones, palm trunks and fronds, marble,

[1] محمد محمد أمين وليلى إبراهيم، المصطلحات الأثرية في الوثائق المملوكية، ص 59.

[2] أسامة عبد النبي قنبر، أحمد علاء لبدة، معايير التصميم الداخلي المستدام في ضوء نظام تقييم الهرم الأخضر، ص ٥٣.

stucco and so on. These materials are characterized by the fact that they are from the surrounding environment and have a high thermal capacity, depending on their thickness. So, they can store thermal energy for long hours during the day and then re-emit it outside in the evening hours, thus achieving a thermal balance between the heat gained and lost through the outer envelope of the building [1].

- He used higher-durability materials, such as different kinds of stones, especially in building walls and facades. The architect utilized some architectural solutions to reduce the negative effect resulting from the heaviness of these stones. He divided the facades into a number of vertical recesses that contain windows and openings (pl. 12). This played a significant role in distributing the load of the building, reducing its heaviness on the ground. In addition, he used lightweight materials in covering these windows, such as turned wood, stucco, and metal grills, to accomplish the same purpose [2].

At the beginning of the Ottoman era, the architect presented another architectural treatment to reduce the heaviness of the building. He divided the facades into two horizontal

[1] Giovani, Baruch, (1998), Climate Considerations in Buildings & Urban Design, John Wiley & Sons, Inc., USA., p. 120.; Hyde, Richard, (2001), Climate Responsive Design: A Study of Buildings in Moderate & Hot Humid Climates, Spon Press, London, UK, p. 115.

[٢] محمد عبد الستار عثمان، (٢٠٠٠)، نظرية الوظيفية بالعمائر الدينية المملوكية الباقية بمدينة القاهرة، دار الوفاء لدنيا الطباعة والنشر، الإسكندرية، ص ٣٩٢.

parts or floors: the ground floor contains a number of shops that are engaged in carrying and supporting the other floor, which is the main one. This architectural treatment is known as the hanging building [1].

- He used lightweight materials in making the roofs of his buildings, such as wood that is formed in various shapes, to achieve both the functional and ornamental dimensions of Islamic architecture. These shapes of wooden roofs include flat ceilings (pl. 13), coffers (pl. 14), and wooden beams (pl. 15) [2]. Sometimes, stone is used in making roofs, which may cause a problem resulting from its heaviness on the walls of the building. Therefore, the architect utilized his innovative solutions to overcome this problem by constructing roofs in different shapes such as gable ceilings, cross vaults, and domes.

5. Indoor Environmental Quality

This standard of the GPRS aims at finding a building with a special nature that contributes to providing efficient outdoor ventilation and increasing indoor air quality, as well as controlling emissions from building materials and enhancing thermal, visual, and acoustic comfort [3]. The Muslim architect considered these previous points while designing his architectural buildings to boost the quality of

[1] ياسر اسماعيل، العوامل المؤثرة على مخططات العمائر الدينية العثمانية، ص 112.
[2] زينب سيد رمضان، (١٩٩٢)، الأسقف الخشبية في العصر العثماني، (رسالة ماجستير، كلية الآثار، جامعة القاهرة)، ص٢٤٤.
[3] أسامة قنبر، أحمد لبدة، معايير التصميم الداخلي المستدام في ضوء نظام تقييم الهرم الأخضر، ص ٥٤.

their internal environment. He utilized innovative tools and architectural treatments such as:

- The facades of the Islamic architectural buildings were built gradually, protruding outwards (pl. 16), to act as refractors for the sun's rays, thus providing shade to large parts of the buildings' walls and units. This architectural treatment played a noticeable role in shading the movement paths in the streets, thus helping to move the hot air upward and get rid of it to be replaced by fresh cool air. Moreover, this treatment caused a reduction in noise propagation and provided calmness to buildings, especially at the blocked ends of these streets. Thus, it helps in achieving both thermal and acoustic comfort.
- The courtyard "Saḥn" (pl. 1, 2, 3) is realized as one of the main architectural elements in most of the Islamic architectural buildings (religious, commercial, and residential) because it was considered one of the most important principles of sustainable architecture. This is due to its ability to adapt to various circumstances and achieve environmental, cultural, aesthetic, and social requirements [1]. The courtyard is employed to perform many functions, such as ventilation, lighting, noise isolation, providing a high degree of privacy, and connecting the internal void to the external void. Moreover, it is utilized as a thermal organizer between

[1] مها صباح الزبيدي، (٢٠٠١)، استخدام الطاقات الذاتية في المدن الجديدة وأثرها في الحفاظ على البيئة، مؤتمر المعايير التخطيطية للمدن العربية، هيئة المعماريين العرب، ليبيا، ص ١٢.

day and night by creating different pressure areas between the outdoor and indoor parts of the building [1]. In addition, the Muslim architect used some architectural solutions to improve the efficiency of the courtyard in decreasing the temperature and cooling the air. Among these solutions is adding a fountain in the middle of the courtyard as well as paving it with materials that play a significant role in absorbing heat, such as bricks and marble.

- The bent entrance is considered a significant architectural solution for applying thermal and acoustic comfort because it provides a large extent of privacy for the inner parts of the building and contributes to decreasing the noise level. Besides, it works to absorb, empty, and renew air inside the building as a result of the transition that happened from the narrow, crooked space of its elements (the entrance, *Dirkāh*, and the corridor) to the larger space in the inner courtyard of the building.
- The *Malqaf* (pl. 17) is considered one of the perfect architectural solutions for increasing ventilation and cooling the air inside the building [2]. It is usually made of wood, and its function is based mainly on the wind's direction. Thus, as a result of the wind movement in Egypt coming from the north-western direction, the *Malqaf* was mostly designed with two closed sides, the southern and eastern, and two open sides, the northern

1 Moore, Fuller (1993), Environmental Control Systems, International Edition, McGraw-Hill, Inc, New York, NY, USA., p. 45-46.

[٢] كمال الدين سامح، العمارة الإسلامية في مصر، ص ١٤.

and western. In addition, its ceiling is made to slope up in order to receive the wind and push it inside the building to get rid of the hot air [1].

- Different types of windows and openings functioned to improve indoor ventilation and lighting, especially the *Mašrabiya* (pl. 4), which particularly appeared in residential buildings. The *Mašrabiya* is a wooden window consisting of very small openings of different sizes, which helps in creating the highest degree of privacy for the house inhabitants. It is considered one of the most successful solutions for covering openings, as it blocks the sunlight and decreases its negative effects. Moreover, the gradual width of its openings, narrowing at eye level and gradually widening upward, works to gradually increase the amount of light entering, which prevents blurring and achieves visual comfort. It also contributes to finding good natural ventilation inside the building, as the movement of fresh air being drawn in from the small lower openings and hot air going outside from the large upper openings [2].
- As mentioned before, the Muslim architect designed the outer structure of his buildings as a means of controlling the weather and natural environment to be suitable for

1 Edwards, Brian & Turrent, David, (2000), Sustainable Housing: Principles & Practice, E. & F. N. Spon, London, UK, p. 123.

2 Creswell (K.A.C.), (1924), An article on Mashrabiyya, B.I.F.A.O., XXIII , Cairo.

human comfort levels [1]. So, he used some materials that are characterized by the fact that they can store thermal energy for long hours during the day and then re-emit it outside in the evening hours, thus achieving a thermal balance between the heat gained and lost through the outer envelope of the building [2]. Besides, he used marble panels in paving courtyards and covering the lower parts of the inner walls, which played a significant role in conditioning the indoor atmosphere.

- Large areas of gardens, orchards, and green spaces that were founded inside houses or were distributed around the various kinds of architectural buildings played a notable role in cooling the atmosphere and purifying the air from harmful gases, thus helping to improve the internal environment of the building.

In addition to previous architectural treatments that help improve ventilation quality and boost thermal and acoustic comfort, the Muslim architect was keen to create visual comfort for his buildings. This was accomplished by caring to the same extent for both the aesthetic and functional aspects of different kinds of architectural elements and units. He invented a number of attractive and innovative designs for each element or unit, as well as giving great attention to ornamenting them with a variety of beautiful

[1] مها صباح الزبيدي، بهجت رشاد شاهين، (٢٠٠٨)، مبادئ الاستدامة في العمارة التقليدية وفق المنظور الإسلامي، ص ٨٧.

[2] Giovani, Climate Considerations in Buildings, p. 120.; Hyde, Climate Responsive Design, p.115.

and well-made decorations such as geometrical shapes, floral ornaments, and inscriptions.

6. Management

One of the most important standards of GPRS is management, which mainly aims at organizing and managing the construction process as well as reducing its negative effects to accomplish social and archaeological development for the surrounding environment. This standard is based on some notable factors, such as the well-choosing of the site and preparing it for the construction process, the existence of a suitable integrated plan and method statement for building operations on the site, caring for the environmental effects of the site to decrease the negative impressions of the construction process, and finally ensuring the proper operation of the building and carrying out the necessary maintenance works to ensure the sustainability of the building and its readiness for a long time [1].

The previous factors were successfully realized in Islamic architecture during the Middle Ages, as the Egyptian state established an important administration called "Diwan *al-'Amā'ir*", which was a specialized diwan for supervising the architectural buildings. The main duty of this diwan was to observe and care for the building regulations in the city, for example, considering the street's rights and preventing the buildings from crossing the street regulation line in the implementation of jurisprudential provisions. Moreover, it

[1] The Housing and Building National Research Center & The Egyptian Green Building Council. (2011), The Green Pyramid Rating System (GPRS), First Edition, Cairo.

was responsible for restoring and repairing the dilapidated buildings, as well as supervising street levelling and cleaning. This diwan was directed by a looker, who in charge of overseeing a number of architects, constructors, painters, carpenters, workers, and other craftsmen [1].

When the ruler or the founder wanted to construct an architectural building, he appointed an important employee to supervise the construction process. This employee was called "*Šād al-'Amā'ir*" [2], and he was responsible for hiring the builders and craftsmen to work on the building site as well as determining their salaries. After that, the "*Šād*" selected an architect to make a design for the building and oversaw the stages of building implementation via a timetable. The architect was also responsible for preparing the site for the construction operation, selecting different types of needed building materials, controlling emissions

[1] عبد المنعم ماجد، (١٩٧٩)، نظم دولة سلاطين المماليك ورسومهم في مصر. دراسة شاملة للنظم السياسية، الطبعة الثانية، مكتبة الأنجلو المصرية، القاهرة، جـ١، ص ٧٩.

[2] It's considered one of the most important jobs during the Mamluk era, as he was responsible for supervising the construction of architectural buildings. The documents of waqf mentioned that he must have some special requirements to be suitable for this job, such as: good knowledge of engineering and construction affairs, religiosity, honesty as well as administrative and political experience. For more information, see:
حسن الباشا، (١٩٦٥)، الفنون الإسلامية والوظائف على الآثار العربية، القاهرة، جـ٢، ص ٦١٧.؛ احمد تيمور باشا، (١٩٧٩)، المهندسون في العصر الإسلامي، دار نهضة مصر للطبع والنشر، القاهرة، ص٤٤-٤٦.؛ عبد الرحيم غالب، موسوعة العمارة الإسلامية، ص٤١٢.؛ عاصم رزق، (٢٠٠٠)، معجم مصطلحات العمارة والفنون الإسلامية، مكتبة مدبولي، القاهرة، ص١٥٧.

and pollutants from machines and tools on site, and finally overseeing the process of removing the building waste and cleaning the surrounding area by putting up a site waste management plan and employing waste recycling workers on site [1].

7. Innovation

This one of the GPRS standards depends on using innovative design ideas and introducing added value that helps in improving the environmental effect of the building and giving a good image about the national and cultural heritage [2].

It can be noted that innovation was one of the distinguished characteristics of the Muslim architect, who showed a great deal of creativity and cleverness in presenting many innovative solutions and architectural treatments to his buildings, as follows:

- showing a notable variety in making plans and designs of the different kinds of architectural buildings such as the Mosque, Madrasa, Sabil & Kuttab, House, Wikala, and so on.
- well-distributing the architectural units and elements of each building and making a symmetry between them, thus giving them the chance to do their specific function

[1] حاتم مرسي حسن، (١٩٨٧)، التأثير الثقافي على المعمار السكنى التجاري في العصر المملوكي بمصر، (رسالة ماجستير، كلية الفنون الجميلة قسم العمارة، جامعة حلوان)، ص 132.

[2] أسامة قنبر، أحمد لبدة، معايير التصميم الداخلي المستدام في ضوء نظام تقييم الهرم الأخضر، ص 55.

properly, as well as presenting their aesthetic aspect side by side with the functional aspect.

- controlling the thickness of walls and ceilings in a way that contributes to enhancing the indoor atmosphere of the building.
- well designating the architectural units and elements such as domes, entrances, facades, minarets, ceilings, arches, and so on. Besides, caring about decorating them with the popular types of Islamic ornaments and in an innovative way that helps in giving them a distinguished and unique appearance.
- coloring and ornamenting the building by using friendly environmental colors that are derived from natural materials and oxides.

The following table (No. 1) shows the great similarity between principles of sustainability in Islamic architecture and the standards of the Green Pyramid Rating System.

Standards of The Green Pyramid Rating System			**Applying Principles of Sustainability in Islamic Architecture**
The standard	**Its objectives**		
Sustainable Site	The site selection		Selecting a distinguished site for buildings, thus most of the Islamic architectural buildings are distributed in many famous and important streets.
	Reducing the Effect of the		- Using various shading and roofing methods

	Sun's Heat		- Constructing the buildings with different heights - The usage of friendly environmental materials that created thermal insulation.
	Increasing the open areas		Finding a variety of open Areas that are used as the ventilation techniques, such as: courtyard, skylight, windows, and so on.
	Reducing light pollution		The usage of friendly environmental lighting means that helped in limiting the intensity of natural light resulting from sunlight and reducing its negative effects
Energy Efficiency	improving energy usage and reducing its negative effects by providing enough shade		- Founding narrow and winding streets and lanes - Making the direction of most city streets and ways from north to south helped in cooling the atmosphere. - The usage of various roofing methods in making ceilings

Water Usage Efficiency	regulate the usage of water and decrease water wastage through several methods		- Provide the different architectural establishments with wells to ensure sufficient pure groundwater. - Constructing Sabils as a very important establishment for saving the drinking water.
	ensure good drainage of water		- Establishing an accurate water drainage system in the different architectural buildings. - Employing the gutter "*Mizrab*" as an essential architectural element for the drainage of rainwater collected over the roof of the building
Materials	the use of regionally procured materials		Using materials that already existed in the Egyptian environment, such as mud brick, stones, palm trunks and fronds
	reducing the negative		creating innovative construction styles to

	effects of materials		achieve the major benefit of these materials and decrease its negative influences
Indoor Environmental Quality	providing efficient outdoor ventilation		<u>The usage of innovative tools and architectural treatments, such as:</u> 1. Protruding outwards facades to act as refractors for the sun's rays and providing shade to large parts of the buildings. 2. The courtyard performed many functions, such as ventilation, lighting, noise isolation, and thermal organizing between day and night. 3. The bent entrance is employed to apply thermal and acoustic comfort. 4. The *Malqaf* is an important architectural solution for increasing ventilation and cooling the air inside the building. 5. Different types of
	increasing indoor air quality		
	enhancing thermal, visual, and acoustic comfort		
	controlling emissions from building materials		

			windows and openings functioned to improve indoor ventilation and lighting. 6. Large areas of gardens, orchards, and green spaces,
Management	managing the building process and reducing its negative effects		- Preparing the site for the construction process. - The existence of a suitable integrated plan and method statement for building operations on the site - Caring for the environmental effects of the site to decrease the negative impressions of the construction process. - Ensuring the proper operation of the building and carrying out the necessary maintenance works
	achieving social and archaeological development for the surrounding environment.		
Innovation	using innovative design ideas.		- The architect presented many innovative solutions and creative architectural

	introducing added value that helps in improving the environmental effect of the building.		treatments to his buildings. - He showed a notable variety in making plans and designs. - He took care of well-distributing the architectural units and elements of each building and making a symmetry between them. - He cared about decorating the architectural units and elements with different types of Islamic ornaments in an innovative way that helps in giving them a distinguished and unique appearance. - He colored the building by using friendly environmental colors that are derived from natural materials and oxides
	giving a good image about the national and cultural heritage.		

Conclusion

This study demonstrated that Islamic architecture has successfully achieved sustainability principles by covering most of its sides. It also proved that the Muslim architect was a pioneer in implementing the principles of sustainability in establishing and designing different types of Islamic architectural buildings. Thus, he was interested in maintaining ecological, social, economic, and cultural balance in the surrounding environment. Besides, the research showed a great compatibility between principles of sustainability in Islamic architecture and the standards of the Green Pyramid Rating System (GPRS), as follows:

- The sustainable site as one of the most significant standards of GPRS has been applied effectively in Islamic architecture because the founders and rulers paid great attention to selecting a distinguished location for their buildings. Moreover, the architects used various methods and architectural treatments to provide shading for the site and decrease the negative effect of the sun's heat, which finally kept this site sustainable.
- The GPRS was interested in ensuring energy efficiency. This standard was implemented efficiently in Islamic architecture by aiming at boosting energy usage, utilizing natural lighting tools, controlling daylight in innovative ways, reducing light pollution, and preventing its negative influences.

- Water use efficiency was highly achieved in the Islamic architectural buildings by organizing the water usage via several tools, reducing water waste, and finding a precise system for water drainage.
- Materials and resources is one of the GPRS standards', which aims at conserving natural resources, encouraging the use of local materials, and decreasing the negative effect of raw materials. The Muslim architect was successful in achieving the requirements of this standard by employing suitable materials for constructing his architectural buildings. He used: (1) local and regionally procured materials that already existed in the Egyptian environment, (2) materials that have a high thermal capacity, thus ensuring thermal isolation for the building, (3) higher-durability materials, and utilized some architectural solutions to reduce the negative effect resulting from their heaviness, and finally, (4) lightweight materials, especially in constructing roofs. In addition, he was keen to control emissions from these materials and reduce their negative effects, as well as implement the major benefits of them by using innovative construction methods.
- The standard of indoor environmental quality mainly depends on presenting sufficient ventilation for the building and improving its indoor air quality. This was effectively applied in Islamic architecture because the architect functioned some innovative tools and architectural treatments to increase the quality of the

internal environment of his buildings and enhance thermal, visual, and acoustic comfort. These tools are represented in protruding outward facades, the bent entrance, the courtyard (Sahn), windows and openings, the *Malqaf*, and so on.

- As considered one of the significant GPRS' standards, the management was an interesting focal point of the Muslim rulers. They were keen on managing and regulating the building process and decreasing its negative influences, as well as carrying out the necessary maintenance works for buildings and putting up a site waste management plan to ensure the process of removing the building waste and cleaning the surrounding area.
- The last of the GPRS' standards is innovation, which was typically realized in various kinds of Islamic architectural buildings, as the Muslim architect showed a major amount of genius and creativity in designing and ornamenting these buildings.

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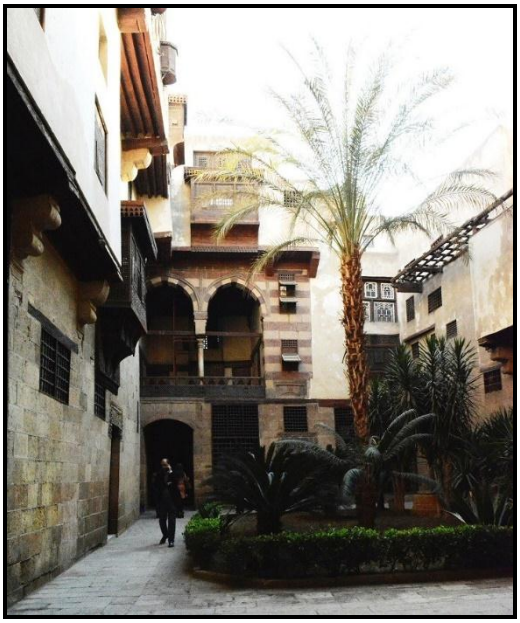
Plates

Pl. 1: The courtyard in the Wikala

(Photographed by the researcher)

Pl. 2: The courtyard in the mosque

(Photographed by the researcher)

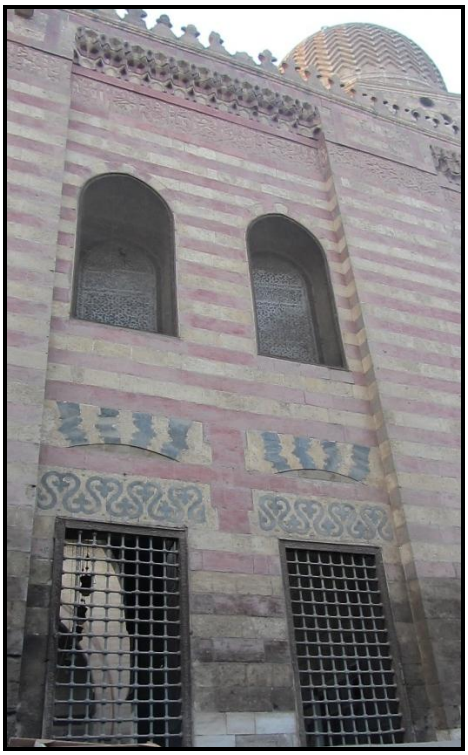


Pl. 3: The courtyard in the house

(Photographed by the researcher)

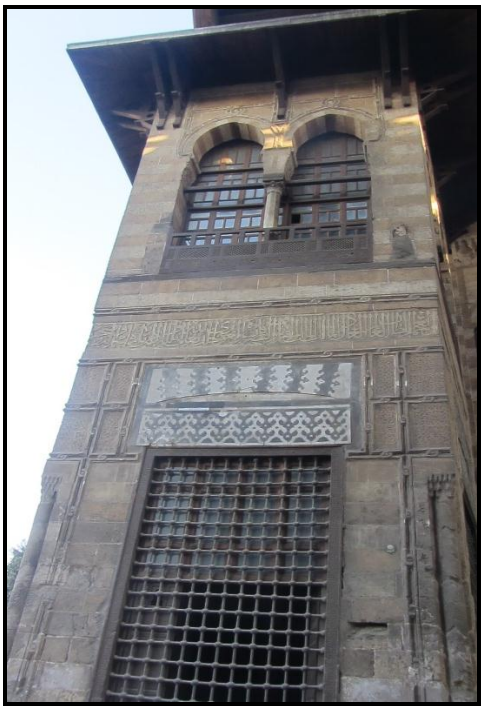
Pl. 4: The *Mašrabiya*

(Photographed by the researcher)



Pl. 5: Examples of windows in the Mosque

(Photographed by the researcher)

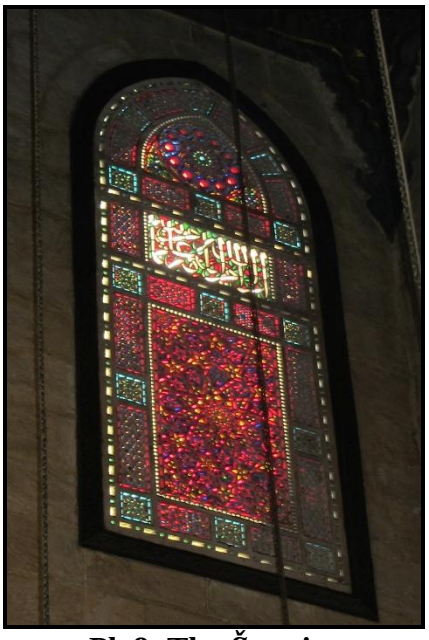


Pl. 6: The Sabil window

(Photographed by the researcher)

Pl. 7: The *Qamariya*

(Photographed by the researcher)

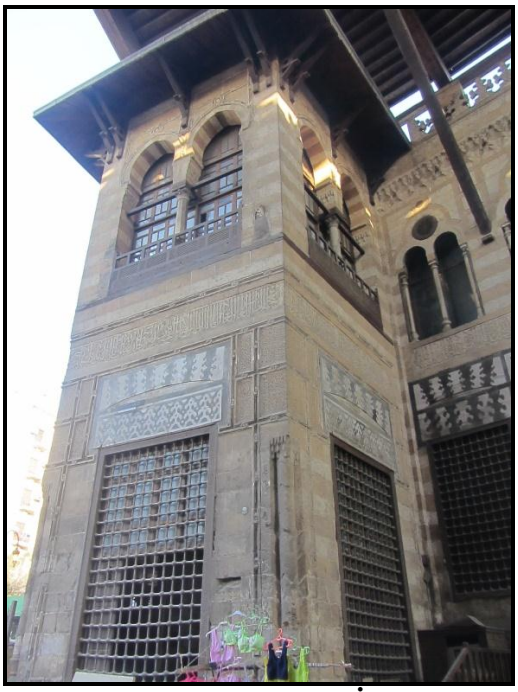


Pl. 8: The *Šamsiya*

(Photographed by the researcher)

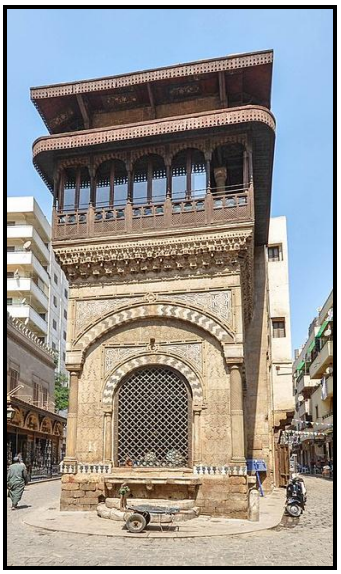
Pl. 9: The *Qandliya*

(Photographed by the researcher)



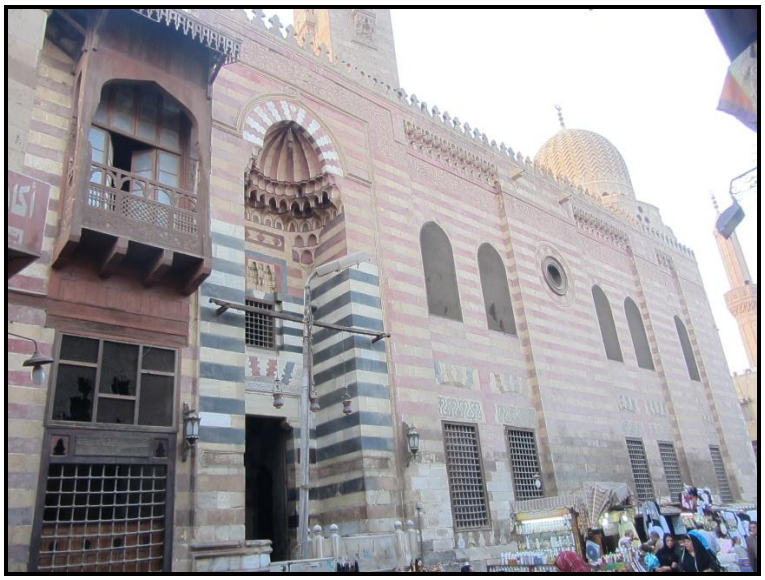
Pl. 10: Sabil of al-Ġūrī

(Photographed by the researcher)



Pl. 11: Sabil of ʻAbd al-Raḥmān Katḫuda

(Photographed by the researcher)



Pl. 12: Facade of al-Ashraf Birsbāy

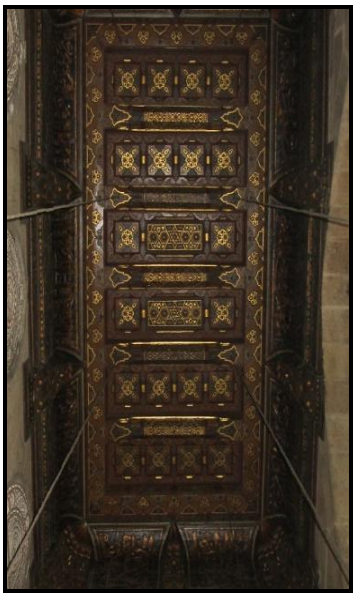
(Photographed by the researcher)

Pl. 13: Flat Ceiling

(Photographed by the researcher)

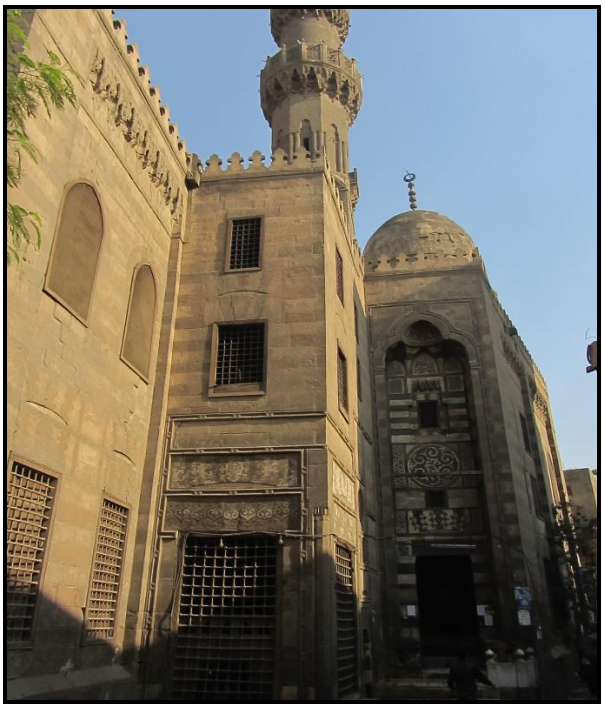
Pl. 14: Coffers

(Photographed by the researcher)



Pl. 15: Wooden Beams

(Photographed by the researcher)



Pl. 16: Façade of Qijmās al-Isḥāqī

(Photographed by the researcher)

Pl. 17: An Example for The Malqaf

(Photographed by the researcher)