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Functional performance of octagonal plan mosques-analysis of octagonal plan mosques in Mosul

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ABSTRACT

The identity of Islamic cities is distinctly manifested through their congregational mosques, primarily characterised by their continuous and stable function, epitomised by the five daily congregational prayers. The performance of a mosque is intricately linked to a set of religious, organisational, structural, and economic determinants, and it is closely tied to the functional and architectural attributes of its elements and spaces. The historic congregational mosques in the Islamic world have predominantly adhered to the architectural model of the Prophet's Mosque, characterised by its rectangular form. In modern mosques, various factors, such as technological advancements and cultural and scientific influences, have led to architectural trends and stylistic innovations. These innovations have aimed to enhance the efficiency and performance of congregational mosques, one of which is the octagonal form. The research problem centered on the utilisation of the octagonal shape and its adaptability in the context of the congregational mosques in the city of Mosul and its suitability for optimal mosque functioning. The research sought to elucidate the appropriateness of employing the octagonal form in congregational mosques by analysing samples with octagonal layouts in Mosul to investigate the extent to which this form influenced the characteristics of the mosque. The research concluded that all octagonal layouts had undergone modifications and expansions to rectify the unsuitable layout, indicating that the octagonal form is foreign to the traditional mosque typology. Furthermore, it is subject to additional alterations to accommodate the functional and architectural requirements of the congregational mosque.

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1. Introduction

The mosque represents the principal religious structure of Islamic civilisation, with the daily congregational prayer being its central function, in addition to its other roles. The mosque typically consists of a central courtyard surrounded by corridors adjacent to a covered prayer hall [1,2]. The mosque served as the initial nucleus in the urban planning of Islamic cities and remained the most significant and active element within them. It is characterised by its multi-functionality, adaptability, continuity, and capacity to expand over time due to the increasing number of worshippers [3] as Islamic cities expanded and their populations grew. The architectural

forms of mosques in the Islamic world have varied over time. Muslims historically adhered to the model of the Prophet's Mosque (rectangular shape), considering it the foundation for designing their mosques. However, this changed with the onset of the 20th century [4]. Technological advancements and their impact on Islamic architecture [5], along with cultural and scientific influences affecting all aspects of life [6], as well as social and humanitarian factors and the influence of prevailing customs and traditions, collectively altered the concept of the modern mosque [7]. One of the emerging forms in modern mosque designs is the octagonal shape,

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distinguished by its formal characteristics and functional patterns within Islamic architecture, and achieving a series of architectural gradations that align with the building's nature, thus enhancing its significance in Islamic architecture [11]. The octagonal shape also carries a spiritual connotation stemming from the Quranic verse: "And there will bear the Throne of your Lord above them, that Day, eight [of them]" (Quran, Surah Al-Haaqqa, 69:17). This shape is created by the composition of two squares on a horizontal plane [8]. The octagonal form is considered the most common regular polygon in Islamic art. The prevalence of the octagonal shape in the Islamic world can be attributed to cultural interactions, natural environments, and collaborations between mathematicians and craftsmen [9]. The octagonal shape notably influenced Islamic architecture, particularly in constructing domed mausoleums, as seen in the Cross-Dome at Samarra and the Dome of the Rock [10]. It also played a significant role in decorative motifs [11]. However, in mosque layouts, the octagonal form did not appear prominently in Islamic history until the early 20th century, primarily through expansion and addition projects, such as the Mosque of Morsi Abul Abbas in Alexandria, Egypt, designed by the Italian architect Mario Rossi in 1928 [12]. The use of the octagonal form subsequently spread throughout the Islamic world. In modern mosques in Mosul, field visits reveal the prevalence of the octagonal shape (both regular and irregular) in some of its mosques, such as the Katib Mosque Al-Hamid Mosque, among others. This can be attributed to the abovementioned factors and various approaches to integrating the octagonal form into mosque sites and adapting it according to functional needs (Researchers' observation). The optimal performance of modern mosques in Iraq is closely linked to two main aspects: determinants and characteristics [6,4,13,14]. Determinants encompass both religious and legal aspects, including full ownership of the land, avoiding harm to neighbours, ensuring alignment with the Qiblah (direction of prayer), and maintaining precision in construction [15,16]. As for Legal determinants involve the standards and regulations specific to mosque buildings in Iraq [6]. Structural determinants involve understanding the structural system of the mosque (i.e., load-bearing walls or structural frame). as lightweight structures are sometimes used in the construction and roofing of mosques and their expansions, despite warnings from the Civil Defense Directorate in Iraq [6,17,18] (Researchers's observation). Economic determinants focus on cost-effectiveness and moderation in planning, design, spatial distribution, and construction methods [16]. Financial considerations often lead to mosque expansions rather than constructing entirely new mosques for economic reasons [19]. These determinants are crucial in ensuring the efficient and sustainable performance of modern mosques in Iraq. The architectural characteristics of the mosque encompass two key aspects: function and configuration. The mosque's connection to configurational characteristics is established by treating its configurational aspects, including the relationship between masses and openings, using similar materials and decorative details to achieve unity among its components [21]. Islamic architecture has a configurational system based on a well-thought-out set of rules and a precise technique that adheres to rhythm, alternating repetition, symmetry, and harmony [22-24]. These architectural characteristics contribute to the overall functionality and aesthetic unity of the modern mosques in Iraq. Indeed, the presence of the octagonal shape in Islamic architecture has been examined in previous studies, as you've referenced [3-6], [25-28]. These studies have highlighted this phenomenon in Islamic buildings, particularly in decorative motifs and domed mausoleums. However, it is worth noting that these studies have not explicitly addressed the use of the octagonal form in mosque layouts and prayer halls. Prominent scholars in the field of Islamic architecture, such as

Creswell [26] and Hillenbrand [29], who are considered authoritative references in Islamic architecture, have not explicitly mentioned the use of the octagonal form in the layouts and prayer halls of congregational mosques in their works. This observation underscores the significance of research in exploring the octagonal form's application in the layouts of modern congregational mosques, filling a potential gap in the existing scholarship. This study can contribute to a more comprehensive understanding of the evolution of mosque designs in contemporary Islamic architecture. To address the research problem concerning "the use of the octagonal form and its adaptability for performance in congregational mosques in Mosul," it is imperative to obtain general characteristics of the congregational mosque and conduct an analytical study of modern octagonal mosques in Mosul. This practical aspect involves three phases. The first phase involved preparing a database table of selected samples, with nine mosques in Mosul chosen for various periods through field visits, interviews, aerial photography, and schematic drawings utilising computer software. The second phase included analysing the collected data, focusing on instances where mosques underwent expansion and modification of certain elements. The third phase comprised the evaluation of mosque characteristics for the selected samples based on predefined theoretical framework variables, leading to the final value for each sample. It was revealed that the octagonal form in mosques is an alien shape, and due to its mismatch with the functional and configurational aspects of the mosque, additions and expansions were made to the prayer hall.

2. The octagon in Islamic architecture:

2.1. The Octagonal Shape:

The octagonal shape is a closed curve composed of eight sides and eight interior angles resulting from the union of straight segments [30], known as the octagon's sides. The points of intersection of these sides are called the vertices of the octagon [2]. It belongs to the geometric shapes in the category of quadrilaterals, particularly squares, since all its sides and angles are congruent [2]. Each angle measures 135 degrees in the octagon, making all its eight angles and sides congruent. Moreover, the octagonal shape possesses the capacity for spatial organisation, enabling the creation of a series of consecutive architectural gradations that align with the nature of the structure, thereby enhancing its uniqueness [3].

2.2. The symbolism of the Octagonal Shape:

The octagonal shape holds significant cultural and religious symbolism. In Islamic architecture, it was first utilised in the mausoleums of the caliphs in Samarra during the third Hijri century. It was also employed in the Dome of the Rock during the Umayyad era [31]. The octagonal shape imparts a dynamic pattern with rotational movement around the central void [32]. However, it is worth noting that the octagonal shape offers fewer advantages for sound distribution, as demonstrated by acoustic simulations of geometric shapes [33].

2.3. The Octagonal Shape in Islamic Architecture:

The octagonal shape has proliferated in Islamic architecture's numerous religious and functional buildings, encompassing various architectural styles. These patterns can be categorised as follows:

a. **Domed Mausoleums:** The "Cross-Dome" model represents the first prototype of a mausoleum in Islamic architecture, signifying a pivotal and groundbreaking development. Its significance lies in its pioneering nature and its establishment of a "type" of architectural structure, which became a design exemplar found in various locations throughout the Islamic world [10]. Over the centuries, the development of domes in Islamic architecture evolved in tandem with advancements in construction techniques and the introduction of new construction materials. Furthermore, the Fatimid domes in Egypt, notably some of them, feature an octagonal shape, with each side containing windows, as observed in the domes of Sheikh Yunus and Sayyida Ruqayya [6]. The octagonal shape has made its appearance in mausoleums as well. In the city of Qadisiyah in Samarra, mausoleums with octagonal shapes emerged, containing an inner octagon, creating the impression of Islamic architecture's ability to encompass one octagon within another [34]. Similarly, in the mausoleums of Kharagan, the octagonal shape was extensively utilised in tombs, employing blocks and decorations [10]. The significance of the "Cross-Dome" architecture lies in its status as a recognised design model found in the architectural masterpieces of Islamic architecture, highly esteemed by many as a gem of world architecture [10]. The Cross-Dome in Samarra and the Dome of the Rock are among the most famous domes in the Islamic world and will be further elucidated as follows (Figs.1 and 2).



Figure 1. The Cross-Dome in Samarra [10]

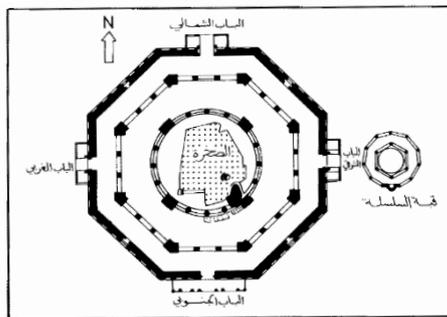


Figure 2. The Horizontal Layout of the Dome of the Rock [19]

b. **Ornamentation:** Ornamentation is a crucial element of both interior and exterior design that enhances the identity and value of a building. Configurational patterns of octagonal design are widely spread through the use of ornamentation. Some designs do not place pattern lines inside square units. In contrast, others employ alternating octagonal edges to establish the pattern line [7], as shown in Fig. 3. Octagons and eight-pointed stars appear in the ornamentation, especially in stone window decoration with perforations to allow light to enter and are often adorned with precious stones (35). In octagonal ornamentation, the principles of repetition and symmetry are applied to create unity in the overall design of heritage buildings in Mosul. Some of these ornaments have been reinterpreted using generative mechanisms and software, significantly influencing conservation efforts and utilising advanced technology [36] (Fig.3).

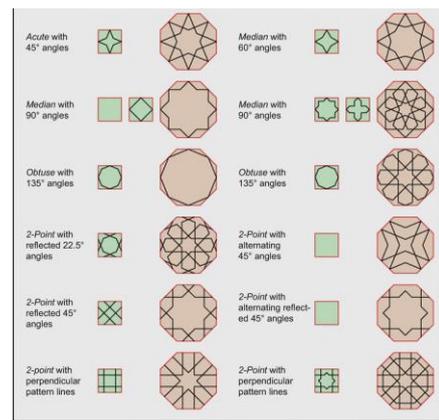


Figure 3. Forms of Ornamentation Derived from the Octagonal Shape [11]

c. **Mosques:** One clear example of using the octagonal shape in mosque design is the Mosque of Morsi Abu al-Abbas in Alexandria, which was constructed upon a mausoleum. Analysing the overall layout of the mosque [12]. It clearly illustrates employing the octagonal shape in configuring the prayer space. After its reconstruction and expansion in 1775, with further renovations completed in 1943, the mosque's layout (Fig. 4) demonstrates the architectural elements of the Mosque of Morsi Abu al-Abbas. Fig. 5



Figure 4. Mosque of Morsi Abu al-Abbas in Egypt [37]

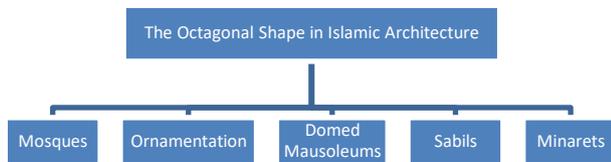


Figure 5. The Uses of the Octagonal Shape in Islamic Architecture (The Researchers)

3. The Performance of Modern Mosques in Iraq:

3.1. Determinants:

These determinants vary among them and can be categorised as follows:

- a. **Legitimacy:** Islamic Sharia encourages adherence to legal determinants in constructing and expanding mosques, including full land ownership [15]. It is also essential to avoid building divisive mosques that may lead to the fragmentation of Muslim congregations. Furthermore, careful consideration must be given to not causing harm to neighbours in terms of mosque design, layout, expansions, and adjacent structures [38]. Among these determinants is the precise alignment with the Qibla during mosque construction, achieved through modern scientific instruments [39]. Therefore, Muslim architects should avoid violating Islamic law by including images and restrooms facing the Qibla, which may lead to architectural similarities with non-Muslim buildings [16]. Islamic law also emphasises the importance of precision in work, including site suitability, attention to rows of worshippers, mosque design, and the design of restroom facilities [16].
- b. **Standards and Regulations:** Examining the specific standards and regulations for modern mosque buildings in Iraq reveals an apparent deficiency and lack of comprehensiveness in these standards. They do not comprehensively cover all aspects of the mosque and consider it separate parts rather than a unified entity. This has had an impact on the general characteristics of the mosque [6].
- c. **Structural Aspects:** The structural aspect of mosque buildings is important, as it represents the load-bearing structure that supports the mosque. This includes both the structural system with load-bearing walls and the structural system that provides flexibility for expansion and the arrangement of internal and external facades [17]. Notably, no specific regulations govern the structural aspects used in mosque construction [6]. Despite warnings from the Civil Defence Directorate in Iraq to avoid using lightweight structures in constructing and roofing mosques and their expansions [18], their frequent use has been observed in mosques in Iraq, including those in Mosul (Researchers's Note).
- d. **Economic Aspects:** Modern mosques should be characterised by cost-effectiveness, simplicity, and moderation in both planning and design, as well as in construction. There should be no extravagance in space allocation and construction methods. Avoiding excessive ornamentation, inscriptions, and intricate designs that could distract worshippers and diminish their devotion inside the mosque [16]. Additionally, it is common to opt for mosque expansion rather than constructing a new mosque due to economic reasons, as it is a cost-effective solution for Muslims [19].

3.2. Characteristics

These characteristics address the functional and configurational variables specific to the grand mosque as follows:

- a. **Functional:** This aspect is directly related to the effective performance of prayer activities, which compels the designer to consider the functional aspect by preserving the elongation of the sanctuary and designing the mosque based on a rectangular or square shape [6]. Additionally, it emphasises the visual connection between rows [20] and the importance of the axis of the prayer hall through the connection between the main entrance and the Mihrab to maintain the directional attribute and continuity. It also highlights the importance of simplicity and regularity in the prayer hall [21] while avoiding slanting walls that cause a loss of space in the prayer area.
- b. **Configurational:** This aspect directly relates to the formal aspect and its treatments. It involves configurational elements like the subordination of blocks and openings using similar treatments of materials, colours, and decorative details that achieve unity among the parts of the same building. Islamic architecture possesses a configurational system that operates through subordination based on well-thought-out rules and a precise system subject to rhythm, repetition, alternation, symmetry, and proportion [40]. Furthermore, the alignment of the prayer hall is essential for the designer at both the overall and component levels. The location of the imam should be central and in front of the rows, signalling the axis around which the prayer hall is oriented [23,24]. It is also important to achieve architectural configurational unity by employing repetition, similarity, symmetry, and proportional relationships among its parts [24].

3.3. The general characteristics of the mosque

The study [6,27,28,44] highlighted the existence of general characteristics for the mosque to align with its primary function, which is the performance of prayers. These characteristics encompass the configurational and functional aspects and emphasise the significance of the mosque's identity's social, spiritual, and cultural dimensions. These characteristics can be summarised as follows:

- a. **Simplicity of General Configuration:** The nature of the mosque contradicts grandiosity and is characterised by the simplicity of its elements and composition [28]. Previous studies have emphasised the importance of simplicity in mosque construction and expansion [41].
- b. **Elongation of the Prayer Hall (Musalla):** The early Islamic mosques were characterised by rectangular prayer spaces, with the front rows being the most elongated and accommodating for the worshippers [13]. This feature has remained consistent in all Islamic mosques, even in modern times [41].
- c. **Emphasis on the Qibla Axis:** The main entrance (gateway) is oriented towards the Qibla, in alignment with the central axis, and facing the Qibla wall to ensure that worshippers do not deviate from the prayer direction [13]. However, the influence of the surrounding streets has hindered the application of this feature in some mosques [6].
- d. **Horizontal Configuration:** This refers to the prophetic hadiths of the Prophet Muhammad (peace be upon him), which emphasised looking downwards or towards the Qibla [42]. Islam also calls for avoiding excessive height and maintaining the horizontal orientation of the mosque in its design and future expansion [43].

- e. **Expandability and Growth Potential:** The prayer hall should be designed to accommodate future expansions in all directions to meet the functional requirements of increasing worshippers over time [41]. This expansion is closely related to economic factors, the focus of expansion, and the spaces and materials used [27].

3.4. Architecture of Local Mosques in the Modern Era in Mosul

The spread of mosques expanded significantly due to functional factors, primarily the increased number of worshippers and the commitment of the local population to perform their religious duties in these mosques (41). However, certain factors emerged in the modern era that led to a shift in the concept of mosques. One of these factors is the presence of wide streets surrounding these structures, which isolated mosques from their immediate surroundings, imbuing them with symbolic and monumental significance. Furthermore, the understanding of mass and space evolved in modern mosques. Mosques began to take on the form of separate or detached masses situated within open spaces. This transformation sometimes eliminates traditional elements like courtyards and surrounding arcades [6]. Additionally, the concept of the external gateway changed. While gateways symbolised the direction of the Qibla (the direction of Mecca) in the past, modern mosques often relate to the mosque's location relative to the surrounding streets. The layout of modern mosques also adopted various forms, including circular or polygonal designs, departing from the conventional rectangular shape. This shift resulted from the influence of contemporary architectural trends and innovative ideas, leading to variations in proportions and heights and a departure from human-scale dimensions [4]. Consequently, the octagonal shape became prevalent in the prayer halls of modern mosques in Mosul, making it essential to study this architectural phenomenon (Researchers' Note).

It becomes evident that several factors have influenced mosques in the modern era, including cultural, scientific, economic, and financial factors aimed at adapting to the changing way of life [6]. The technological factor, represented by the proliferation of technology and its impact on architectural and structural aspects and the use of modern construction materials and structures, has led to significant changes in modern mosques [5]. Additionally, the social and human factors, manifested in the evolution of human relationships and the prevailing customs and traditions, have reshaped the concept of the modern mosque. This is further compounded by integrating the urban structure with societal requirements and developments, resulting in changes in the community's perception of the modern mosque [7].

4. Methodology

After reviewing the theoretical framework specific to the research, the research structure will be presented to determine how to approach and address the research problem, as illustrated in Fig. 6. The research objectives are achieved through the review and study of plans, aerial images, and ground images of the selected samples, following a methodology that encompasses three aspects:

The first aspect (database table of the selected samples): The prayer halls of Mosul's mosques are distinguished by their diversity in terms of materials used and their external configuration. The city has gone through political periods that have led to this diversity in the prayer halls of its mosques, with critical periods being before and after 2003. Therefore, dealing with the flexibility of the samples will involve determining the regularity of the samples (regular octagonal/irregular octagonal), their

construction dates, and the number of construction phases. This information was obtained by reviewing documents, maps, and official records through consultation with the Urban Planning Directorate in Nineveh (Table 1). See Fig. 7.

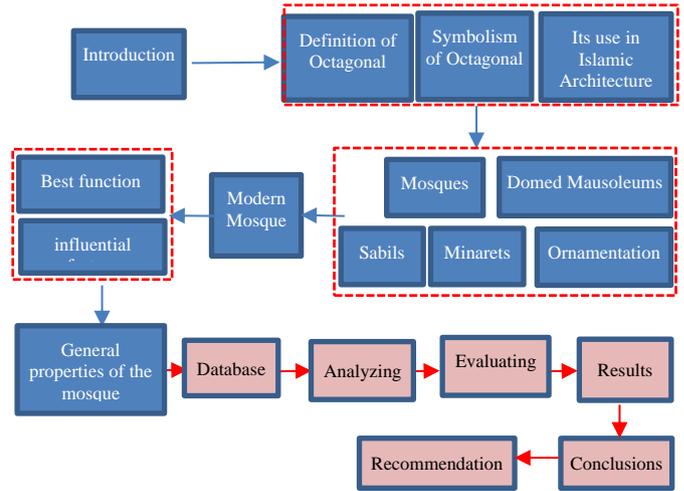


Figure 6. Methodology of the Research (The Researchers)

Table 1. Database Mosques in Mosul

Encoding	
Layout	
Ground Images	
Aerial Images	
Number of Expansion Phases	
Construction Date	
Octagonal (Regular/Irregular)	
Sample	
Expansions	
Octagonal Shape	
The Researchers documented the sample using the standard measuring tape and a Galaxy-11mega pixels	
Camera Drum 2mavic pro	
Conducting interviews with mosque officials	
Sunni Endowments Directorate	
The Researchers	
Source of the information	

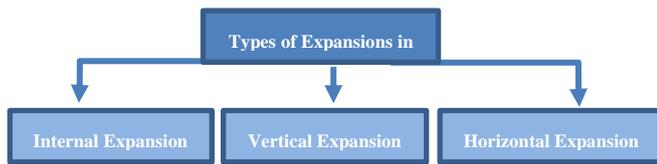


Figure 7. Types of Expansions in Mosques

The Second aspect (Table for Evaluating the Flexibility of Selected Samples): Based on what has been explained through the first and second aspects and what has been presented in the theoretical framework of the research, flexibility will be assessed through the following variables (Courtyard Elongation - Axis Orientation - Form Unity - Block Dependency - Compatibility of Materials Used). These variables will be compared with the first and second aspects, and relevant variables will be discovered to obtain high accuracy in unifying the variables. Table 2 will be used to obtain possible values by evaluating the variables according to (0-1-2) to achieve high accuracy in the results, and the weights for these variables will be standardised.

Table 2. Evaluating the Selected Samples (by the Researchers)

Variable	Prayer Hall Elongation	Axis Orientation	Form Unity	Block Dependency	Compatibility of Materials Used	Final Value
Sample						
Weight	2	2	2	2	2	10

5. Practical study

Criteria for Selecting Research Samples: A total of 9 samples of mosque buildings in Mosul were selected based on the significance of these samples in the field of modern mosques, the impact of applying architectural characteristics, their temporal and spatial diversity, and the effect of these mosques on the communities they serve. These samples were divided into regular and irregular categories and encoded, as shown in Table 3.

6. Results and discussion

The results were reviewed according to the practical steps as follows:

6.1. The results shown in Table 4 for the selected samples database revealed the following:

- The regular octagonal shape represents 77.78% of the selected samples, while the irregular octagonal shape represents 22.22%.
- The percentage of having only one expansion phase represents 77.78% of the selected samples. In contrast, 11.11% of the selected samples have two expansion phases, and 11.11% have not undergone any expansion work.

- A single donor funds the expansion, representing 11.11% of the selected samples. In comparison, multiple contributors fund 77.78% of the selected samples, and 11.11% of the selected samples have not undergone any expansion work.
- Aerial and ground images show variations in the configuration of the octagonal mosque and its surroundings after the expansion work.

Table 3. The symbol for each mosque (the Researchers)

Name of Mosque	Symbol
Al-Katib	M1
Al-Hamid	M2
Ahmed Ismael	M3
Ibad Al-Rahman	M4
Al-Aghawat	M5
Abdullah Al-Jader	M6
Allah Akbar	M7
Al-Dabbagh	M8
Al-Ahmed	M9

6.2. The results specific to the selected samples' data analysis (Table 5) are as follows:

The sample M7 was excluded from the analysis as it underwent no addition or expansion work.

- Horizontal expansion is achieved in all selected samples at a rate of (100%). Vertical expansion is achieved at a rate of (12.5%), and there is no internal expansion in these samples (0%).
- The percentage of expansion direction is opposite to the Qibla direction by (75%), while the right direction of the Qibla is at a rate of (37.5%). The left direction of the Qibla is at a rate of (37.5%), with the lowest percentage being in the direction of the Qibla by (12.5%).

The prayer hall represents the highest space for expansion at a rate of (75%), followed by the arcade element at a rate of (37.5%), then the garden element at a rate of (25%), and finally (mosque services - outside the mosque boundaries) at a rate of (12.5%) for each of them.

6.3. The results (Table 6) revealed the evaluation of the samples according to the architectural characteristics after expansion works on these octagonal-shaped samples as follows:

- Horizontal overall configuration is the most achieved characteristic in the selected samples, with an average score of 1.89 out of 2 for all selected samples.
- The characteristic of overall simplicity in configuration is the least achieved, with an average score of 0.89 out of 2 for all selected samples.
- The prayer hall's elongation characteristic achieved an average score of 1.33 out of 2 for all selected samples.

The characteristics of focusing on the Qibla axis and adaptability to expansion both achieved an average score of 1.45 out of 2 for all selected samples.

7. Conclusion

- The octagonal layout of modern mosques departs from the traditional rectangular plan, giving a sense of centrality and reducing emphasis on the Qibla wall. This allows for decreased accommodation of worshippers in the front rows and is characterised by high adaptability to expansion.
- The prayer hall's octagonal layout changed due to expansion works. The practical study reveals that the octagonal shape (whether regular or irregular) does not meet the functional and configurational requirements of the mosque. Evidently, the values of mosque characteristics considered in the practical study increase after expansion work on the octagonal prayer hall.
- The Aerial and ground images provide significant insights into the flexibility of the octagonal shape, as they showcase various expansion works using different materials (solid and lightweight) that have influenced its overall configuration.
- Horizontal expansion is the most prevalent type of expansion in mosques in general, and the expansion direction depends on the prayer hall's location within the mosque. The yard area is the most susceptible to prayer area expansion.

8. Recommendation

- Conduct future studies (comparative studies) to study the phenomenon of octagonal planning in mosques compared to other countries. And analyse the phenomenon in different architectural styles by conducting similar research.
- Establish clear standards for mosque design by specifying a rectangular layout that preserves the mosque's functional and architectural characteristics and avoiding using other layouts, including the octagonal layout.
- Changing the octagonal design of the mosque through expansion and renovation to comply with the architectural characteristics of the rectangular model of the Prophet's Mosque.

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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