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# Using golden ratio in detecting the aesthetics of Mosque facades: The case of contemporary Mosques in Erbil city

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ABSTRACT

From ancient Greece till the present, the golden ratio has been considered one of the most significant criteria of beauty in art and architecture. Architectural forms are part of the visual language that is bound by the rules of geometry and proportion. This study aims to identify the extent to which contemporary mosques in the city of Erbil utilize the golden ratio in the aesthetics of their facades. The research attempts to answer the question: was the golden ratio implemented in designing the facade of contemporary mosques in Erbil? The study adopted a mixed quantitative and qualitative analysis method. To achieve the study's aim and answer its questions, six mosques built in the last decade in Erbil were selected. Qualitatively, survey and documentation followed. Quantitatively, Phi matrix software, AutoCAD, and graphic software were applied as a mathematical approach. The study concluded that only one case used the golden ratio in the design of its façade by 100%, while it did not exceed 75% in most other mosques. The study draws the attention of designers and architects in the field of mosque architecture to the adoption of the golden ratio in the designs of mosque facades because of its role in achieving the aesthetic aspect.

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## 1. Introduction

The role of building facades is essential, as they are often the first element that people notice, particularly in the case of historically significant buildings. Facades serve as a visual element that can make a building unique and distinguish it from others, based on its aesthetic value [1]. The subjectivity of perception, taste, and judgment has made the topic of aesthetic value a perpetual subject of discussion in architectural theory. The assessment of aesthetics is related to the individual's experiences, which can change based on various factors such as time, location, actors, and atmosphere. Historical evidence confirms that theories of aesthetic value in architecture have been developed based on building proportion. Geometrical proportion is considered a fundamental geometric attribute inherent in all forms of life [2]. The Holy Quran states that humans embody the optimal proportions that are mirrored in the universe and are the core of God's creatures [3]. Humans possess the most exquisite and harmonious proportions, reflecting the divine harmony of existence. As stated in the Quran (AL-Tin 4:30), "لَقَدْ خَلَقْنَا الْإِنْسَانَ فِي أَحْسَنِ تَقْوِيمٍ" means "We have created man in the best composition" [4]. Geometrical proportions have been used as a self-guided method of creating aesthetically pleasing designs for a long time [5,6]. Among these proportions, the golden ratio is considered the primary indicator of aesthetic quality in buildings that follow the natural laws of proportion [7]. Throughout the history of art and architecture, architectural designs that utilize the golden ratio as an organizational and proportional framework have been regarded as examples of aesthetic and structural order [8].

The study of geometry in architecture involves various aspects, such as its structural application, modular dimensions, and mystic meanings. It is essential to incorporate geometry in the plan and facade of buildings to claim a comprehensive understanding of this knowledge [9]. Design based on this knowledge involves accurately identifying geometric elements at different

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levels and their respective positions in the design, understanding the relationships between them, and utilizing composition techniques to convey their meanings [10]. While modern principles have replaced traditional principles of mystical principles, geometry, and networking, it is still crucial to comprehend these principles when studying traditional architectural works to gain a holistic understanding of their designs [11].

In Islamic architecture, geometry has a significant role in design. In the architecture of some nations, geometry, and proportion, especially its golden ratio, have been used, but for each to a certain extent and in a special meaning. Islamic architecture beautifully and coherently incorporated the material components and their associated meanings to connect with God. This use of geometry as a symbolic language format is a unique feature of Islamic architecture[12]. In Islam, a mosque is considered to be a center of spiritual content and a platform of communication, it develops unity and society among the Muslim communities[9]. The major activity of the mosque is to facilitate *salat* to be performed in *jamaat (praying in a group)*. Many other activities in favour of the daily life of an individual Muslim or a Muslim community are accomplished through a mosque. Thus, a mosque has become a central part of any Muslim settlement all over the world [13,14].

Throughout history, it has been realized that a proportion system can assist both the ordering and the perception of buildings. Proportioning systems provide an aesthetic rationale for the dimensions of form and space. They can visually unify the multiplicity of elements in an architectural design by having all its parts belong to the same family of proportions. They provide a sense of order in the facades and spaces of architectural works [15]. One of the most significant outcomes of architecture's goal is the facade because it reflects the coordination relationship of the whole (technical and aesthetic) in any building. In other words, a building's exterior is like a dressing that can reveal characteristics like personality, morale, style, social class, culture, and economic circumstances [6].

In Islamic architecture, different styles adopted various methods in designing mosque facades. In Erbil city particularly for contemporary mosque designs architects tried to refer to styles of Islamic architecture in designing mosques. There is a lack of application of proportions in façade design according to the golden ratio as an aesthetic value. This study aims to examine the existing contemporary mosques in Erbil city in terms of adopting the golden ratio in the aesthetic of facade design.

## 2. Previous related studies

In architecture, different nations have employed geometry and proportion, particularly its golden form, to varying degrees and with specific meanings. For example, ancient Greece utilized geometry in architecture and other arts based on humanism, which emphasized the importance of humans [16]. The results of many scientific and psychological types of research show that the most beautiful surfaces and shapes from the point of view of human beings are those that have a golden ratio in their dimensions [8].

Salama (2019) in his study has aimed to demonstrate that Islamic art and architecture are based on mathematical and geometrical concepts, specifically the golden ratio, which gives them a sense of aesthetic harmony with the surrounding universe. The result proved the use of sacred geometry as a guiding principle in Islamic art and architecture [17]. Handayani and Soewardikoen (2018) investigated the use of the Golden ratio in mosque facade design by examining three mosques. The findings suggested that the use of mathematical principles in mosque design can contribute to achieving a sense of harmony and balance in the built environment [9]. In the same way, Wafaei Baneh et al. (2021) demonstrate how the Golden Ratio, a crucial element of sacred geometry, lies at the foundation of Islamic architecture and decoration. The Golden Ratio is used in design to create a sense of harmony and balance that makes it aesthetically pleasing and comfortable [12].

In addition, the principles of the Golden Ratio were employed in other research conducted by Adnan, Raja Shahminan, and Ahmad in 2022 to analyze the minbar's aesthetic value and internal proportion. To determine whether elements of the minbar satisfied the requirements of the golden ratio, the research focused on the front and side elevations of the minbar [18]. Khajeh Pour and Soheili's study (2015) aimed to investigate the proportion values used in Safavid architecture and their relation to functionality. The study examined governmental buildings, mosques, and bridges, and found that the proportion values varied depending on their purpose. The study emphasizes the importance of functionality in determining proportion values in Safavid architecture [19]. Besides, Aljubori and Alalouch (2018) observed that the Golden Ratio partially manifests in the compositions and shapes of deconstructivist buildings. This has significant ramifications for architects and designers because they may improve the aesthetic appeal and create a feeling of harmony and balance in designs by using the Golden Ratio [8]. Likewise, Mahdipour and Saradj (2012) examined the use of the golden proportion in the facades and quadruple vaulted porticos of a mosque. The study identified a geometrical shape based on the Fibonacci series as a standard measure to detect the presence of the golden ratio. The study highlights the significance of intentional design in achieving aesthetic appeal in the mosque [3].

In the same way, Goudarzi et al. (2020) focused on investigating the golden proportions present in the Shah Mosque in Isfahan. The study employed Phi matrix software to analyze the mosque's design and identify the golden proportions within it. This study underlines the importance of creating harmony and proportion in mosque design [4]. Moreover, Jamil (2017) chose the Shah Faisal Mosque of Pakistan as a modern dome-less case study. His study discusses the development of innovative architectural and design elements of the mosque and their benefit to the various functions in terms of space planning, proportion, and aesthetics, which used descriptive analysis as a way to assess the effectiveness of the cultural and religious role being played by the mosque at a national and global level [20]. The current study tries to answer the question, did contemporary mosques in Erbil city apply the golden ratio in their façade design?

## 3. Mosque building

The mosque is a building that has a strategic role in Muslims' lives [20] Mosque serves as a gathering place for Muslims to pray, either individually or in groups[21]. These prayers may be performed by large or small groups of members if they are carried out during the prescribed times [22,23] The English word mosque comes from the Arabic word “masjid”, which means “a place for prostration” [23,24]. The mosque acts as a landmark or becomes a point of reference for Muslim people [25]. Most mosques in Muslim countries have common architectural elements as a sign of a place of prayer [26,27] Geometry constitutes an essential and fundamental element in art and architectural engineering. Within the authorized framework of geometry, all aspects of a structure, including its components and mass, can be established, and given identity [28, 29] The analysis of the mosque geometrically was first conducted at the Great Mosque of Kairouan in Tunisia, where it was discovered that the principle of the Golden Section could potentially be employed as a reconstruction guide for a mosque dating back to around 670 AD [30,31,32].

## 4. Methodology

To achieve the research objective, the current study adopted a mixed-method methodology (qualitative and quantitative). In the qualitative method, survey and documentation were followed. For the quantitative method, the study applied the golden ratio as a mathematical approach for calculating proportions. The study also applied Phi matrix software for calculating the golden ratio through rectangular proportioning and AutoCAD software for drawing elevations. Furthermore, graphic software is used for illustrating the drawings.

### 4.1. Golden ratio

The golden ratio is often known as the golden mean, divine proportion, golden section, and golden number [33]. It was used in buildings by ancient civilizations such as the Egyptians and Greeks, notably the Great Pyramid and the Parthenon Temple [34] There are varieties of definitions of the golden ratio. “Father of Geometry” is the nickname of Euclid who was the first one to discuss the golden ratio definition and said, “A straight line to have been cut in extreme and mean ratio when, as the whole line is to the greater segment, so is the greater to the less” [35] From Euclid through Kepler to Penrose, many mathematicians have spent years studying the characteristics and uses of the golden ratio. The Greeks found the "Section" property and termed it the golden section, which Martin Ohm classed as "golden" in 1835. The golden ratio, which is approximately equal to 1.61803398, is an irrational number having an infinite number of digits after the decimal point [36].

Mathematically, it is represented by the irrational number (1 + square root of √5) / 2, indicated by the Greek character, or by the formula a/b = (a + b) / a, where a and b are variables that can be any non-negative number [15]. The ratio of the largest variable (a) to the smallest variable (b) equals the ratio of the total of the two variables (a, b) to the greatest variable (a) and equals the golden ratio = 1.168 as shown in Fig. 1 [11,37].

$$\textit{Golden ratio} = \frac{a}{b} = \frac{a+b}{a} = \varphi = 1.61803398 \quad (1)$$

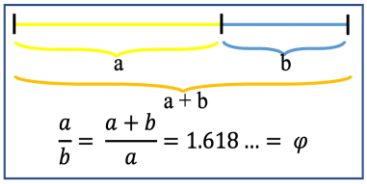



**Figure 1**.Golden Ratio through line segment [38]

### 4.2. Proportion by rectangular

The golden rectangle is a rectangle of the ratio between its sides that represents the golden ratio [37] Furthermore, the length-to-width ratio is the same as the value of φ. By referring to Figure (1) and Equation (1), the golden rectangles indicate the Golden ratio = a + b/a = b/a = 1. 61803398. The golden rectangle is represented by drawing a square and then drawing a line from the midpoint on one side to the corner of the opposite side, then drawing an arc from the corner to the length of the side with the midpoint, finally, the golden rectangle is completed as shown in Fig. 2, [8].

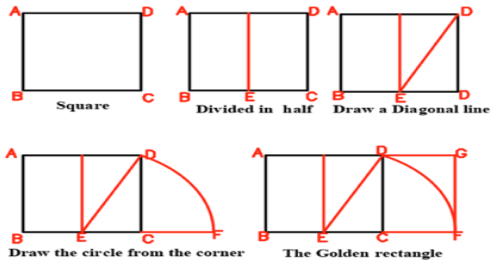



**Figure 2.** Steps of constructing a two-dimensional representation of the golden rectangle. (Authors Adapted from Aljubori and Alalouch, 2018).

### 4.3. Phi matrix software

The Phi Matrix program is a graphic analysis and design tool for architects and designers who want to employ the golden ratio principles in their work to produce harmonious designs. It was developed and launched in the United States in 2010 by Phi Matrix LLC, and it has since received multiple upgrades and enhancements. The program enables designers to apply the golden ratio to their works more accurately and systematically, which is especially valuable in industries like architecture and graphic design. Since its debut, this program has gained popularity among designers who want to use the golden ratio to produce aesthetically attractive designs. Users have given the program favorable feedback, praising its simplicity and adaptability [4].

### 4.4. Case studies

For applying the methodology and achieving the research aim, six samples were selected in Erbil city. The mosques were built by local architects. The selection of case studies in this research was based on two main criteria. Firstly, the building had to have been constructed within the last decade to study whether the architects utilized golden ratio ideas in mosque designs to improve their aesthetic features.

**Table 1**. Case studies description (Authors)

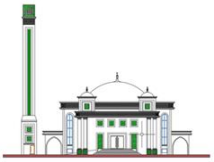
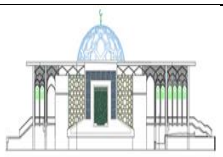
| Name | Year of built | Location | Elevation/Facade |
|---|---|---|---|
| **Madina mnawara Mosque** | 2014 | Koya Road in the New Hawler district |  |
| **Firdaws Mosque** | 2022 | 120th Road in Farmanbaran district |  |
| **Sami Gardy Mosque** | 2007 | Koya Road in the Havalan district |  |
| **Zin city Mosque** | 2014 | Massif Road in the Zin City neighborhood |  |
| **Haji Ibrahim Mantk Mosque** | 2023 | 120th Road in Roshenbiry district |  |
| **Future City Mosque** | 2022 | Massif Road in Future City neighborhood |  |

**Table 2.** Results of each mosque's main entrance façade with a comparison to the Golden Ratio (Authors)

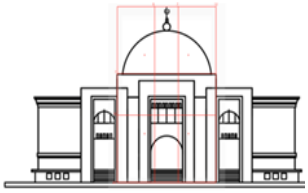
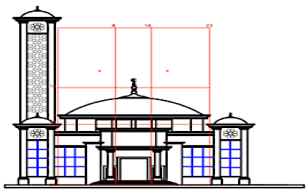
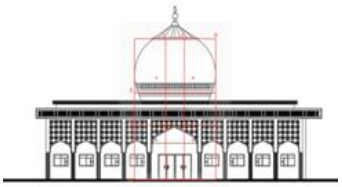
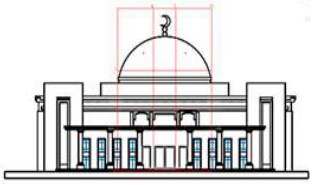
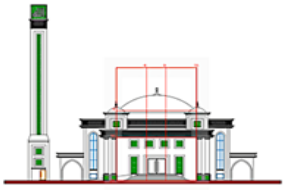
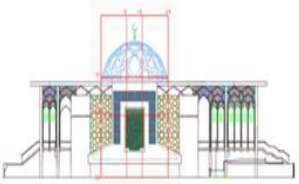
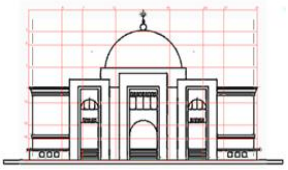
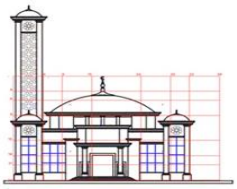
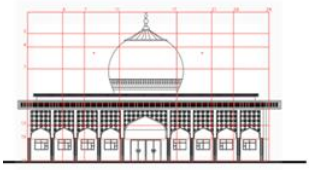
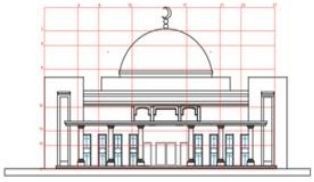
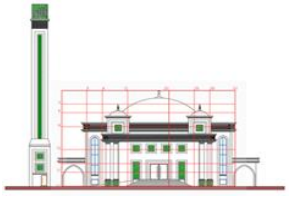
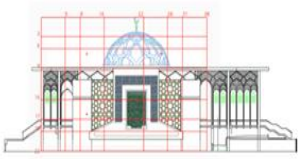
| Name | Main Elevation | Actual Dimension with Golden Ratio | | Golden Ratio | Golden Ratio % |
|---|---|---|---|---|---|
| | | Height (m) | Length (m) | | |
| **Madina Mnawara Mosque** |  | 19.1<br>$\varphi = 19.1/11.8$<br>$\varphi = 1.618$<br>$1:\varphi$ | 11.8 | $\varphi = 19.1/11.8$<br>$\varphi = 1.618$<br>$1:\varphi$ | 100 % |
| **Firdaws Mosque** |  | 24.1<br>$\varphi = 24.1 / 22.1$<br>$\varphi = 1.09$ | 22.1 | $\varphi = 35.75 / 22.1$<br>$\varphi = 1.618$<br>$1:\varphi$ | 67 % |
| **Sami Gardy Mosque** |  | 17.2<br>$\varphi = 17.2 / 8.6$<br>$\varphi = 2$ | 8.6 | $\varphi = 13.92 / 8.6$<br>$\varphi = 1.618$<br>$1:\varphi$ | 123 % |
| **Zin City Mosque** |  | 16.69<br>$\varphi = 16.69 / 10.93$<br>$\varphi = 1.52$ | 10.93 | $\varphi = 17.68 / 10.93$<br>$\varphi = 1.618$<br>$1:\varphi$ | 93 % |
| **Haji Ibrahim Mantk Mosque** |  | 20<br>$\varphi = 20 / 15.10$<br>$\varphi = 1.32$ | 15.10 | $\varphi = 24.43 / 15.10$<br>$\varphi = 1.618$<br>$1:\varphi$ | 81% |
| **Futuer City Mosque** |  | 22.4<br>$\varphi = 22.4 / 14.7$<br>$\varphi = 1.52$ | 14.7 | $\varphi = 23.78 / 14.7$<br>$\varphi = 1.618$<br>$1:\varphi$ | 94% |

**Table 3.** Results of each mosque's main elevation and comparison to the Golden Ratio (Authors)

| Name | Main Elevation | Actual Dimension with Golden Ratio | | Golden Ratio | Golden Ratio % |
|---|---|---|---|---|---|
| | | Height (m) | Length (m) | | |
| **Madina Mnawara Mosque** |  | 19.22 | 30.90 | $\varphi = 30.90/19.22$<br>$\varphi = 1.618$<br>$1:\varphi$ | 100 % |
| | | $\varphi = 30.90/19.22$<br>$\varphi = 1.618$<br>$1:\varphi$ | | | |
| **Firdaws Mosque** |  | 36.6 | 39 | $\varphi = 39/24.1$<br>$\varphi = 1.618$<br>$1:\varphi$ | 65 % |
| | | $\varphi = 39/36.6$<br>$\varphi = 1.06$ | | | |
| **Sami Gardy Mosque** |  | 17.2 | 27.83 | $\varphi = 27.83/17.2$<br>$\varphi = 1.618$<br>$1:\varphi$ | 100 % |
| | | $\varphi = 27.83/17.2$<br>$\varphi = 1.618$<br>$1:\varphi$ | | | |
| **Zin City Mosque** |  | 16.70 | 28.42 | $\varphi = 27/16.68$<br>$\varphi = 1.618$<br>$1:\varphi$ | 105 % |
| | | $\varphi = 28.42/16.70$<br>$\varphi = 1.70$ | | | |
| **Haji Ibrahim Mantk Mosque** |  | 20 | 36.20 | $\varphi = 32.36/20$<br>$\varphi = 1.618$<br>$1:\varphi$ | 107 % |
| | | $\varphi = 36.20/20$<br>$\varphi = 1.81$ | | | |
| **Futuer City Mosque** |  | 22.4 | 47.8 | $\varphi = 36.24/22.4$<br>$\varphi = 1.618$<br>$1:\varphi$ | 131% |
| | | $\boldsymbol{\varphi = 47.8/22.4}$<br>$\boldsymbol{\varphi = 2.13}$ | | | |

Secondly, there had to be availability and accessibility to the building's architectural documentation, as well as the possibility to conduct field visits and take measurements. The cases were, Madina Mnawara, Firdaws, Sami Gardy, Zin City, Haji Ibrahim Mantk, and Future City as shown in Table 1.

## 5. Results

Based on applying the golden ratio on the main entrance with the dome and front façade of the selected case studies, the current study discussed each part separately. As shown in (Table 2), the main entrance and the dome analysis are illustrated. The rectangular golden ratio is applied to the facades of each case. In Madina Mnawara Mosque, the real dimensions of its height to the length are the same as the proportions of the golden ratio. Accordingly, Madina Mnawara Mosque achieved a total golden ratio. While, in Firdaws Mosque the actual dimensions of its height to the length were (24.1 – 22.1) meters, respectively, therefore, it's φ= 1.09 which is less than 1.618; but after applying the golden rectangle, the results showed that the dimensions should be (35.75 - 22.1) meters respectively, to achieve a ratio of 1: φ. The dimensions of the main entrance in Sami Gardi Mosque were (17.2 - 8.6) meters respectively instead of (13.92 - 8.6) meters, in this way, the φ = 2 which is more than the golden ratio, consequently, the percentage also is more than 100%. In Zin City Mosque, the dimensions of the main gate were (16.69 – 10.93) meters for its height to length sequentially. Accordingly, the φ is equal to 1.52, which is near to the golden ratio (1.618), in this way Zin City Mosque is the second mosque to reach close to the golden ratio. Moreover, Haji Ibrahim Mantk Mosque's entrance dimensions were (20 - 15.10) meters, to reach a ratio of 1.618, the dimensions should be (24.43 - 15.10) meters for each of its height and length. In the entrance façade of this mosque with a dome, the presence of a golden ratio was only 81%. Furthermore, Future City Mosque is reached 94%. This is because its real dimensions were (22.4 - 14.7) meters which resulted in a φ equal to 1.52 which is less than the golden ratio. Approximately, Zin City and Future City Mosques were very close to each other by achieving only 93% and 94% respectively, from real proportions.

On the other hand, in **(**Table 3**)**, the main façade dimensions are illustrated. The golden ratio was applied to the facade of the Medina Mnawara Mosque and the Sami Gardi Mosque completely. This is because the proportions of height to width reached 1.618. In Firdaws Mosque, the φ equal 1.06 is less than the real proportion of the golden ratio of 1.618, meaning that there is a lack of applying the golden ratio, achieving only 65%. On the other side, three mosques are exceeding the ratio of 1.618, which are Zin City, Haji Ibrahim Mantik, and Future City. This also led to the disappearance of the golden ratio in the façade proportions. In the three mosques, the φ values were over the real portion by (1.70, 1.81, and 2.13) sequentially.

## 6. Conclusion

Based on the results, the study concluded that the Mosque of Madina Mnawara was the only mosque among the six cases that had totally achieved the golden ratio in both the façade and the entrance. While, in the façade of the Firdaws Mosque, the actual dimensions of its height to length were not in perfect accordance with the golden ratio. Moreover, the main entrance dimensions of Sami Gardi Mosque exceeded the golden ratio. Furthermore, the dimensions of the main façade, with the golden ratio applied to Sami Gardi Mosque. Additionally, the main gate dimensions in the mosques of Future city and Zin city were close to the golden ratio required proportions. By comparing the two facades that were adopted in this study, it turns out that each part of the building has a great role in showing the aesthetics of the facade if it is carefully studied, especially when applying the golden ratio as a design approach. The study recommends that architects who are involved in the design of the modern mosques should consider the adoption of proportional principles, such as the golden ratio, to enhance the aesthetic value of the facades.

**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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This study didn't receive any specific funds.

**Data availability**

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

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