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Modelling Approach In Islamic Architectural Designs

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Abstract

Architectural designs contribute as one of the main factors that should be considered in minimizing negative impacts in planning and structural development in buildings such as in mosques. In this paper, the ergonomics perspective is revisited which hence focuses on the conditional factors involving organisational, psychological, social and population as a whole. This paper tries to highlight the functional and architectural integration with ecstatic elements in the form of decorative and ornamental outlay as well as incorporating the building structure such as wall, domes and gates. This paper further focuses the mathematical aspects of the architectural designs such as polar equations and the golden ratio. These designs are modelled into mathematical equations of various forms, while the golden ratio in mosque is verified using two techniques namely, the geometric construction and the numerical method. The exemplary designs are taken from the Sabah Bandaraya Mosque in Likas, Kota Kinabalu and the Sarawak State Mosque in Kuching, while the Universiti Malaysia Sabah Mosque is used for the Golden Ratio. Results show that Islamic architectural buildings and designs have long had mathematical concepts and techniques underlying its foundation, hence, a modelling approach is needed to rejuvenate these Islamic designs.

Keywords: Architectural designs; Ergonomics; Integration; Ecstatic; Modelling approach

Introduction

Since the advent of the new millennium, Islam has faced challenges from all aspects, so as the Muslim followers from all modes of life. Islamic buildings, art and designs seem to be put to fade by the introduction of current and non traditional, the so-called contemporary designs of the modern world. Mosques are such Islamic buildings that are undergoing such transformations.

Mosque is a sacred building around the world for followers of the Islamic faith. The word mosque, in Arabic, means "the place where we bow". According to Frishman and Hason (2002), it can be defined as a place where the Muslims do their prayers and other activities. Eventhough mosques have played a big role in past years as hospitals, religious schools (madrasahs) and shelters for the travellers (musafirs), the primary purpose is to serve as a place where Muslims come together for their prayers. Its general importance to the Muslim community is well

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known and this is demonstrated through the Islamic architectural designs.

A mosque is more than just a building, but encompasses a prayer hall (musalla), multipurpose hall or community hall, open markets as well as natural and man-made parks and gardens (Suhaimi, 1994). It is full of symbolism and each part serves a purpose. However, its maximum capacity can only be seen during the Friday prayers and the festive Eid prayers.

Topology Of Mosque

Islamic architectural design and construction combines various secular and religious styles that span over all of the Islamic history. The bulk of Islamic architectural characteristics are visible in mosques, tombs, forts and palaces, but the evolution of Islamic architecture can be seen best in the construction of the mosques. The first three mosques that were originally constructed on the Arabian Peninsula (Al Kaaba, Quba and An Nabawi mosques) were simple, open spaces. There was significant evolution over the next 1,000 years as mosques began to acquire distinctive features like domes, minarets, courtyards and grand entry ways that have been adapted to various cultures around the world. An example is Cairo which had been nicknamed as the "city with a thousand minarets". Many of the mosques in the Islamic world are characterized by imposing steeples, ornate interiors and opulent architecture as shown by the Istanbul's Blue Mosque in Turkey of figure 1.

However, the mosque has a basic standardized assembly of component parts. The whole architecture of a mosque is orientated to the north (Kiblah), towards the Islamic holy shrine, the Kaaba (Masjid Al Haram) in the holy city of Makkah in Saudi Arabia. Besides the Kiblah, placed is the mihrab which is the central and most decorated feature of any mosque. Another component is the pulpit (minbar). It is always positioned to the right of the mihrab. The minbar consists of a staircase leading to a platform where the imam will deliver the khutba. A wooden platform (dikka) is in line with the mihrab but reached in its own stairs where the Qadi reads and recites the Quran (Frishman & Hason, 2002). The dome is the hallmark of a mosque and resembles an integral part of the Islamic architecture. It is often placed above the main prayer hall.

Figure 1. Istanbul's Blue Mosque built between 1609 and 1617.

Another component is the minaret which is a tall and slender tower, built near or into the mosque structure. It is so designed such that the adhan by the muezzin can be heard by the worshippers from a far distance, besides serving as local landmark. Another significant part of the mosque is the portal which then conceals the interior of a building from the outside view.

Modelling Approach And Concept

Since architectural designs in mosques portrays the impact of Islamic civilization of a particular time (Ibrahim, 2009), hence the objective of this paper is to highlight the geometric shapes and designs used in three mosques, namely, the UMS Mosque, the Bandaraya Mosque, both of which are in Kota Kinabalu, and the Sarawak State Mosque. The golden ratio and its numerical analysis are carried out on the UMS mosque since data of its structural plan can be obtained from the Department of Development and Maintenance of Universiti Malaysia Sabah.

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Geometric Shapes and Designs

Islamic mathematicians like Al-Buzyani (998 AD.) and Giyath Al-Din Jamsid Al-Kashi (1429 AD.) had written a manual on the basic geometric principles and its applications in architecture. The manual contained issues on the 2D composite geometrical designs, fundamental lines of the dome and gateways, and these formed the characteristics of the muqarnas shaped-dome. This manual had also become the technical guidelines with mathematical principles for the architects, developers and building supervisors.

Golden ratio

Golden ratio is a famous terminology used in the fields of mathematics, science and architecture. It is a unique ratio of two terms such that the ratio of the larger term and the smaller term is in the way as the smaller plus the larger to the larger term (Mehrdad, 2005). It can also be an irrational number, such as 1.618 or ratio that is often encountered in geometry, art, architecture and other areas. This is due to the fact that some artists and architects believe that the use of the Golden Ratio can make the most pleasing and beautiful shapes and designs (Adrian, 2009). Golden ratio is also known as the golden section, golden mean, or divine proportion, and denoted by Greek letter, (phi) where it can be written in its numerical quantity as $\Phi = \frac{1+\sqrt{5}}{2}$, or 1.618025751 (Clement, 2005). The presence of several proportions of the golden ratio in the ratios of 5:3, 8:5, and square root of two proportions are found throughout all of architecture (Frings, 2002). The sequence of ratios of consecutive numbers of their sequences converges to ϕ: 1.618 (Rossi & Christopher, 2002). Stakhov (2005) had then proposed the fundamentals of a new kind of mathematics based on the golden section for further applications of the Fibonacci numbers.

Golden ratio can be derived with a number of geometric constructions, each of which divides a line segment at the unique ratio of two terms when the ratio of the larger term to the smaller term is in the way as the smaller plus larger to the larger. Golden ratio in architecture has also been linked with an aesthetical value and it shows that, the architecture looks beautiful mathematically with the existence of this proportion (Steven, 2007). The use of Golden Ratio can be seen in mosques of the Persian architecture such as Taj-al-Mulk dome (1088 AD), Ali Qapu (1597-1688 AD) and Shaykh-Luft-Allah (1601-1628) as shown by Figure 1, Figure 2 and Figure 3 respectively (Mehrdad, 2005).

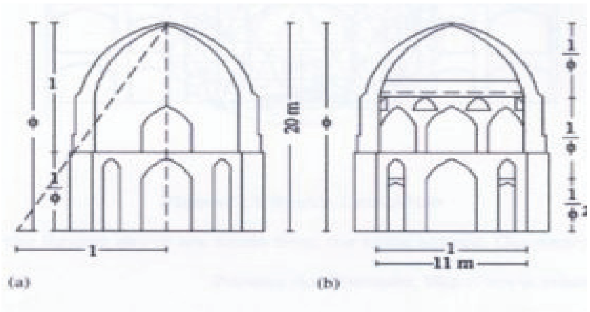

Figure 1: Taj-Al-Mulk Dome

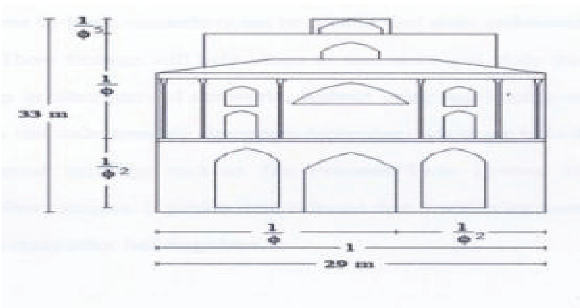

Figure 2: Ali Qapu Building

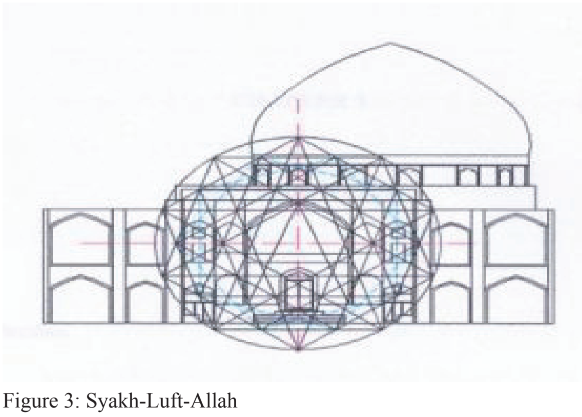
Figure 3: Syakh-Luft-Allah

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Methodology

Two techniques are implemented so as to obtain the golden ratio in mosques which are the geometric construction and numerical analysis (Reynolds, 1999). The first technique involves the use of geometric approach by the partition of line and generation of the golden rectangle. The followings steps are the algorithms for line partitioning of the golden ratio:

i.) Draw any length of AB.
ii.) Next, the rectangle with the length AB and width AB/2 is drawn.
iii.) A diagonal is drawn from A to the opposite corner of A.
iv.) Then, the width (AB/2) is then subtracted from the diagonal by drawing an arc with the width as the radius.
v.) The diagonal is then divided into 2 segments as a result of the intersection of the arc with the diagonal.
vi.) Finally, the longer segment of diagonal is rotated onto the adjacent side, AB. The intersection point, C subdivides AB into the golden ratio. C is called the golden section of AB.

The drawings of the golden ratio line partitioning are illustrated in Table 2 in the Appendix. The followings are the steps to derive the golden ratio using the generation of the golden rectangle.

i.) Draw a square having AB as a side.
ii.) Divide AB into half.
iii.) Then draw from the middle of the side AB to the opposite corner.
iv.) Rotate this diagonal till it cuts the line AB at C.
v.) A new square is formed with line BC as its side.

Steps i) till iv) are repeated and a golden ratio progression will be obtained across the extended line of AB as shown in Figure 4. The complete drawings of the golden rectangle generation can also be found in Table 3 in the Appendix.

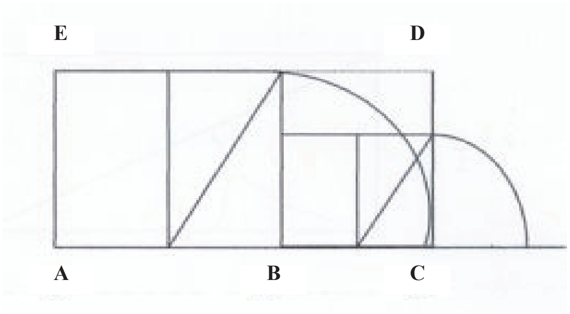

Figure 4.Golden Rectangle Construction

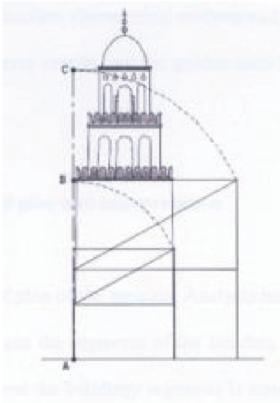
Figure 5. The Minaret with 2nd Geometric Construction

The second technique is by the numerical analysis method, conducted in Excel. Initially, the structural measurements are calculated from the plan of the mosque. The analysis is carried out by dividing the greater to the lesser of the building given by the formula; Ratio = a/b ≈1.61812297where a = the greater length and b = the lesser length. Subsequent calculations follows using the same basic idea of dividing the greater by the lesser. The golden ratio is determined from the *n*th geometric construction that is applied to the mosque plan where *n* is the number of times the geometric construction is employed. An example is shown in Figure 5 above where the second geometric construction has been taken to evaluate the golden ratio of the minaret. The length of the tower, the proportions of the tower, namely the measurements of the height and the width will be taken to verify the golden ratio.

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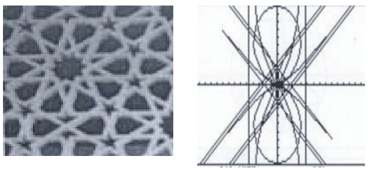
Results

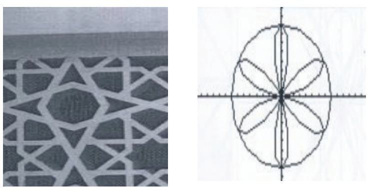
The followings are shapes and designs taken from the respective three mosques. The shapes and designs exhibit various geometric sides on the walls, domes and portal of mosques. The designs can be drawn using polar coordinates in electronic tools like graphic calculators or using computer softwares such as Maple.

Shapes and Designs



$r_1=5 \sin 2\theta \tan \theta$
$r_2=5 \tan 2\theta \tan \theta$
$r_3= -5 \tan 2\theta \tan \theta$
$r_4= -5 \text{ kos } 2\theta \tan \theta$

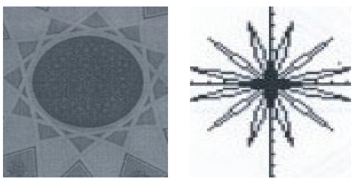
Figure 6 : Ten Geometric sides on wall of UMS Mosque



$r_1=8(\sin 3\theta)^2$

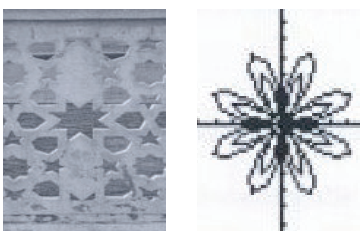
$r_2=8$

Figure 7 : Eight Geometric sides on wall of Sarawak State Mosque



$r_1=22(\sin 3\theta \text{kos} 3\theta)^2$

Figure 8 : Twelve geometric sides on dome of Sarawak State Mosque

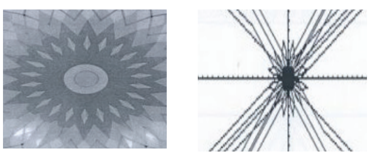


$r_1=9 \sin 2\theta \text{kos} 2\theta$

$r_2=13(\sin 2\theta \text{kos} 2\theta)^2$

$r_3=7 \sin 3\theta$

Figure 9 : Eight Geometric sides on portal of Bandaraya mosque



$r_1= \tan 2\theta \tan 3\theta$
$r_2= -\tan 2\theta \tan 3\theta$
$r_3= 6\sin \theta kos 3\theta$
$r_4= 3\sin \theta kos 3\theta$
$r_5= 8\sin 3\theta kos 3\theta$
$r_5= -8\sin 3\theta kos 3\theta$

Figure 10 : Twenty-two Geometric sides on dome of Bandaraya mosque.

Geometric Construction

Figure 11 shows the golden ratio of the second geometric construction. The length of a square is measured from the base to the first floor of the minaret. The length of AB is then divided into half. The diagonal is drawn from the middle to the opposite corner and rotated to cut the line AB at C, as indicated in the figure.

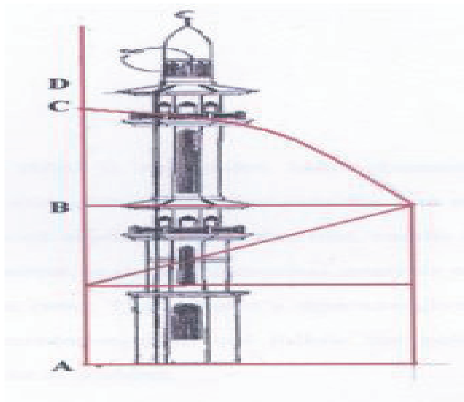


Figure 11 : The Minaret with 2nd Geometric Construction

Results show that the partitioning relations between the first floor and the second floor on its height are not of the golden ratio. The numerical analysis carried out on all the geometric constructions are listed below.

Numerical Analysis of the Golden Ratio of the UMS Mosque

Table 1 shows the numerical analysis carried out on the architectural plan of the roof, minaret and portal of the UMS Mosque. Several plans and views are taken and calculated so as to validate the different numerical calculations on the structural plan. It can be seen that the building ratios of the UMS mosque are far off from the range of the desired golden ratio of Reynolds (1999) and Mehrdad (2005).

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Table 1. Numerical Analysis of the Structural Plan of the UMS Mosque.

Mosque Structure	Structural Measurements	Golden Ratio
Roof Plan : i) master	{Length AB is74.4m;Longer segment BD is 42.0m}	$\Phi_{roof}^{master} = \frac{74.4}{42} = 1.7714$
ii) Plan 1	{Length AB is 25.4m;Longer segment BD is 15.4m}	$\Phi_{roof}^{Plan1} = \frac{25.4}{15.4} = 1.6494$
iii) Plan 2	{length AB is 35.0m; Longer segment BC is 21.7m}	$\Phi_{roof}^{Plan2} = \frac{35.0}{21.7} = 1.6129$
Minaret 1	{length AD is 40.2m; Longer segment AB is 23.4m}	$\Phi_{\min aret\_1} = \frac{40.2}{23.4} = 1.7179$
Minaret 2: i)Plan 1	{length AG is 24.0m; Longer segment AB is 15.6m}	$\Phi_{\min aret\_2}^{Plan1} = \frac{24.0}{15.6} = 1.5384$
ii)Plan 2	{length AG is 24.0m; Longer segment AF is 17.7m}	$\Phi_{\min aret\_2}^{Plan2} = \frac{24.0}{17.7} = 1.3559$
iii)Plan 1	{length AD is 20.1m; Longer segment AE is 15.6m}	$\Phi_{\min aret\_2}^{Plan3} = \frac{20.1}{15.6} = 1.2885$
Portal: i)View 1	{length AE is 37.5m; Longer segment AD is 23.4m}	$\Phi_{roof}^{View1} = \frac{37.5}{23.4} = 1.6025$
ii) View 2	{length AE is 37.5m; Longer segment AC is 18.9m}	$\Phi_{roof}^{View2} = \frac{37.5}{18.9} = 1.9841$
iii) View 3	{length AE is 37.5m; Longer segment AB is 21.9m}	$\Phi_{roof}^{View3} = \frac{37.5}{21.9} = 1.7123$

Discussions

Geometric shapes and designs exemplified in Figures 6, 7, 8 and 9 have shown the similar designs of the star patterns of Lee (1987) and Broug (2008). The designs shown can be modelled using tools such as the graphic calculator. However, the intricacies cannot be drawn to detail as exhibited in the true art and crafts.

Geometric constructions of the golden ratio are used to investigate the mathematical relationships in the mosque structure of the structural plan of roofs, minarets and portal. The geometric lines that have been drawn did not cut the structures proportionately according to the golden ratio. Numerical analysis in Table 1 shows that the values do not fall within the golden ratio range. Similarly, the geometric construction techniques are carried out on all the respective component structures of the UMS Mosque.

Hence, results indicate that the principle of the golden ratio does not exist. Further studies are then suggested to be conducted on the other mosques and their impacts on the functional uses as indicated by Mohamad (2010). Designing of mosques for other multipurposes and activities have evolved such as studied by Özaloglu and Gurel (2011) in Turkey where Turkish mosques have transformed as a social point of congregation. This is in line with the works of Suhaimi (1994) where he suggested that ergonomically designed buildings are cost effective in reduced air-conditioning and electricity bills, increased functional objectives based on human factors and activities, both classical and systemic, as well as space, location and environment of the mosques.

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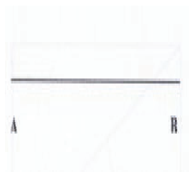
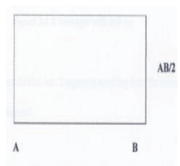
Conclusions

The respective mosques are found to have still some cultural and Islamic influence in their shapes and designs. More efforts are required in inculcating Islamic building concepts and preserving the cultural Islamic forms of architectural designs as far as Islamic heritage is concerned. Eventhough the mathematical concept of the golden ratio is not administered in the structural building of the UMS mosque; the mosques studied in this work have stood with its ecstatic values much to the scrutiny of art, cultural and heritage lovers.

Appendix

Table 2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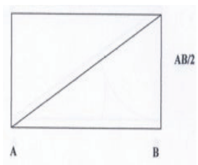	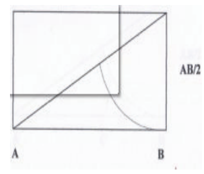
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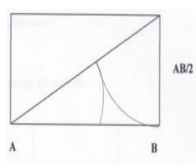	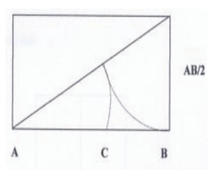
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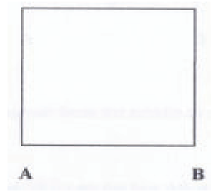
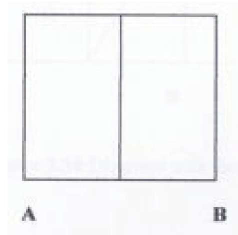
Table 3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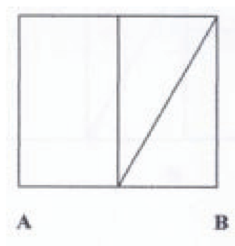	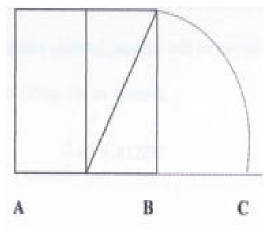
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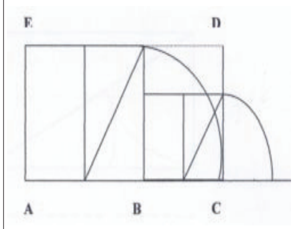	
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