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Comparison of Ethnomathematical Concepts in Mosque Architecture in North Sumatra: A Case Study of Al-Mashun Grand Mosque and Al-Osmani Grand

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ABSTRACT

Indonesian mosque architecture in North Sumatra is full of ornaments and shapes that are not just of visual interest, but also philosophically and mathematically very relevant. Nevertheless, very little research exists that specifically compares the application of ethnomathematical concepts in two very old mosques, the Al-Mashun Grand Mosque and the Al-Osmani Grand Mosque. Indeed, these two mosques are a peculiar combination of domestic culture and external influences, as expressed by the building's form and decoration. This research evaluated architectural aspects with the help of indicators like geometric shapes (circle, triangle, square, rhombus), three-dimensional objects (block, cube, tube, hemisphere), and geometric transformations (reflection, translation, rotation). This research aims to: (1) establish the application of ethnomathematical concepts to Al-Mashun Grand Mosque architecture; (2) to establish the application of ethnomathematical concepts to Al-Osmani Grand Mosque architecture; and (3) compare the results of the application of the concept in the two mosques. This study applies qualitative descriptive research with the case study approach, comparing data using comparative descriptive analysis of field observation, visual documentation, and reading study. The results of this study show that Al-Mashun Grand Mosque emphasizes symmetrical octagonal buildings and intricate ornaments in the Middle Eastern style of design, while Al-Osmani Grand Mosque emphasizes rectangular buildings and Malay ornamentations. Both employ geometric transformations that enhance harmony, order, and cultural identity. These findings illustrate that Islamic architecture serves not merely as a space for worship but also as a conduit for integrating cultural values with mathematical principles.

Keywords: *Ethnomathematics, Islamic Architecture, Geometry, Local Culture Mosque*.

Perbandingan Konsep Etnomatematika pada Arsitektur Masjid di Sumatera Utara: Studi Kasus Masjid Raya Al-Mashun dan Masjid Agung Al-Osmani

ABSTRAK

Arsitektur masjid di Indonesia, khususnya di Sumatera Utara, memiliki kekayaan bentuk dan ornamen yang tidak hanya bernilai estetis, tetapi juga sarat dengan makna filosofis dan matematis. Namun, kajian yang secara khusus membandingkan penerapan konsep etnomatematika pada dua masjid bersejarah, yaitu Masjid Raya Al-Mashun dan Masjid Agung Al-Osmani, masih jarang dilakukan. Padahal, kedua masjid ini merepresentasikan perpaduan budaya lokal dan pengaruh luar yang unik, yang tercermin dalam struktur dan ornamen bangunannya. Penelitian ini menilai elemen arsitektur berdasarkan indikator bentuk geometri (lingkaran, segitiga, persegi, belah ketupat), bangun ruang tiga dimensi (balok, kubus, tabung, setengah bola), serta transformasi geometri (refleksi, translasi, rotasi). Penelitian ini bertujuan untuk: (1) mengetahui penerapan konsep etnomatematika pada arsitektur Masjid Raya Al-Mashun; (2) mengetahui penerapan konsep etnomatematika pada arsitektur Masjid Agung Al-Osmani; serta (3) membandingkan hasil penerapan konsep tersebut pada kedua masjid. Penelitian ini menggunakan metode deskriptif kualitatif dengan pendekatan studi kasus, dan data dianalisis melalui analisis deskriptif komparatif terhadap hasil observasi lapangan, dokumentasi visual, serta kajian literatur. Hasil penelitian menunjukkan bahwa Masjid Raya Al-Mashun menonjolkan struktur segi delapan simetris dan ornamen kompleks bergaya Timur Tengah, sedangkan Masjid Agung Al-Osmani lebih menekankan struktur persegi panjang dengan ornamen khas budaya Melayu. Keduanya sama-sama menerapkan transformasi geometri yang memperkuat harmoni, keteraturan, serta identitas budaya. Temuan ini menegaskan bahwa arsitektur Islam tidak hanya berfungsi sebagai tempat ibadah, tetapi juga sebagai media integrasi antara nilai budaya dan prinsip matematis.

Kata Kunci: *Arsitektur Islam, Budaya Lokal, Etnomatematika, Geometri, Masjid*

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1. Introduction

Mathematics is a subject that can support the progress of education in Indonesia with the hope of being able to train students to be able to think critically, practically, systematically, realistically, and creatively (Widiana et al., 2023). Mathematics is an abstract science that is deductive related to numbers or numerical language that uses logical thinking methods in studying the relationship between patterns, shapes, structures and spaces (Logan & Pruska-Oldenhof, 2022; Shirawia et al., 2023). One approach that relates mathematics learning to real life is ethnomathematics, which involves applying mathematical concepts within the context of culture and the surrounding environment (Suherman & Vidákovich, 2025; Putri, 2024). The architecture of the mosque, as part of Islamic cultural heritage, preserves various geometric shapes, symmetrical patterns, and transformations that reflect both aesthetic values and mathematical concepts (Arion, 2024; Susanti et al., 2025).

Culture or budaya, comes from the Sanskrit language, specifically from the word buddhayah, which is the plural form of buddhi (meaning mind or intellect). This term is interpreted as referring to things related to the human mind and intellect (Mardhiyya et al., 2024). In its development, culture encompasses not only customs and art, but also reflects in the work of humans, including building architecture (Al-Adilee, 2024; Cao et al., 2024). One form of cultural heritage that is rich in aesthetic and symbolic value is the mosque, which often utilises mathematical principles in its construction (Al Khalifa & Lafi, 2025; Khanzadeh, 2024). This makes the mosque one of the objects of ethnomathematical study, such as in the architecture of the Al-Mashun Grand Mosque and the Al-Osmani Grand Mosque in North Sumatra, which feature unique geometric shapes, symmetrical patterns, and spatial transformations worthy of comparison.

Ethnomathematics refers to the examination of mathematical ideas as they occur in practice in culture. Ethnomathematics unites mathematics and ordinary cultural life, as observed in architecture (Cesaria et al., 2025; Fauzi et al., 2022). Through the integration of local culture information into learning, ethnomathematics offers a new approach to the provision of mathematics education that is more applicable and helpful to students (Kabuye Batiibwe, 2024; Hidayat, 2025; Nur et al., 2021). Essentially, it explores how math is being applied in some cultural environments so that individuals can better relate to and understand the topic. Although ethnomathematics has just recently gained attention in schools, its aspect of fostering understanding remains topical (Machaba & Dhlamini, 2021). It recognizes that mathematics, to a certain extent, is not only universal but socially and culturally dependent. It brings together various components of culture such as symbols, language, and habitual practices, which determine how a society learns and uses mathematical principles (Thanheiser, 2023).

It is one of the strengths that ethnomathematics allows for direct linkages between mathematics learning and cultural practices, thus enhancing understanding (Aulia & Afri, 2023). When integrated into school curricula, it enables learners to experience learning more contextually and meaningfully (Aritonang & Lubis, 2024). Evidently, in most cases, we are living with unknowing ethnomathematics; a clear illustration is seen in mosque architecture (Hajazizi & Gooya, 2024; Sarhangi, 2012). Mathematical concepts in building design not only serve the structural roles but also carry deep cultural significance. Religious abodes and traditional homes frequently utilize geometric motifs grounded in local tradition (Bo & Abdul Rani, 2025; Husni, 2024). Symmetry and geometry prevail in mosque structures, resulting in functional but highly symbolic buildings. They create visual balance, harmony, and beauty and represent the connection between human beings, the divine, and the universe (Baydoun et al., 2024; Maksoud et al., 2025; Rashdan & Ashour, 2024).

Indonesian mosque design embodies ethnomathematical application more than any other structure. Mosques are not just hubs of spirituality but also spiritual significance and social identity (Hoelzchen, 2022; Yulistyoningsih et al., 2025). Research has confirmed that mosque architecture employs geometric forms circular, square, triangular, and symmetrical patterns in domes, arches, calligraphy, mosaics, and carvings (Nazli et al., 2015; Purniati et al., 2020; Qais, 2024; Zuliana et al., 2023). The geometric rules are employed to form functional rooms as well as provide religious comfort and visual pleasure to the faithful (Shaw, 2022). The focus on mosques, rather than other quintessentially traditional venues like temples or palaces, is derived from their unique blend of ritual function, congregational worship, and symbolic significance. In addition, the prevalence of mosques across Indonesia creates the potential for broad comparative analysis to be conducted, making them eminently suitable to examining the interlude between art, mathematics, and culture.

North Sumatra, being culturally rich and ethnically diverse, offers an extremely interesting setting to examine the application of ethnomathematics in mosque architecture. The mosque is not only a place for worship but also a symbol of cultural and historical heritage of the local community. Two such mosques, now architectural landmarks of this province, are the Al-Mashun Grand Mosque and the Al-Osmani Grand Mosque. Both of the two mosques have rich histories and reflect the rich culture in their construction.

The Al Mashun Grand Mosque in Medan is one of the icons of historical Islamic architecture in the city of Medan which has high religious and cultural values (Uchie & Deni, 2025). The Al-Mashun Grand Mosque was built by Sultan Ma'mun Al Rasyid Perkasa Alamsyah in 1906 and inaugurated in 1909 (Dwi Pratiwi & Efendi, 2025). The Al-Mashun Grand Mosque is one of the most stunning mosques in North Sumatra. The mosque has Malay, Arabic, Indian, and Spanish architectural styles, giving its design a uniqueness. The Al-Mashun Grand Mosque's uniqueness can be seen from the structure of the building, being an octagonal edifice with a big dome in the middle surrounded by four small domes. Architectural elements such as arches. The stained-glass windows, and geometric ornamental elements exhibit a balance of mathematical elements and Islamic architecture.

At the same time, Al Osmani Mosque was established by Sultan of Deli VII Osman Perkasa Alam in 1854 utilizing selective wood material (Nasution et al., 2022). The mosque was given the name Osmani because this mosque was built during the time of Sultan Osman (Maritza et al., 2021). The Al-Osmani Grand Mosque is designed in Malay, Indian, Chinese, and European styles, which can be seen in the shape of the roof, which is simpler but still retains typical ornate elements. In comparison to the octagonal shape of the Al-Mashun Grand Mosque. Al-Osmani Grand Mosque focuses on a rectangular shape with an addition of vibrant colors within. The intricate carvings, sturdy pillars, and distinctive motifs that decorate the walls substantiate the individuality of the use of Islamic architectural principles along with indigenous culture elements.

Both mosques have architecture and design reflecting deep cultural values grounded on the convergence of mathematics and local culture in their architectural styles. The second reason to compare these two mosques is that they share similar architectural qualities and were built during the Deli Sultanate period, within the same area, that is the city of Medan. It was compared to determine the form of the geometric design in both mosques, as per Malay tradition, and to verify whether it is identical or different.

Based on the background description, problem identification, and study limitations and goals, the primary issue of this research is comparing the application of ethnomathematical principles in the Al-Mashun Grand Mosque's and Al-Osmani Grand Mosque's Medan City, North Sumatra, design. The two mosques are full of geometric and symbolic elements showing the integration between mathematical concepts and local values. However, comparative studies that examine the difference and similarity of the application of ethnomathematical concepts in both mosques are still extremely limited.

2. Method

This study employs a qualitative descriptive approach with a focus on exploring and comprehending the use of ethnomathematical concepts in mosque architecture. This approach was employed because it enables researchers to explore the phenomenon in-depth through data interpretation obtained from field observation, documentation, and literature research. The research approach adopted is a case study with an emphasis on architectural analysis of two historic mosques in North Sumatra. To this effect, a case study is the intensive examination of the Al-Mashun Grand Mosque and the Al-Osmani Grand Mosque as bounded systems whose analysis units are their buildings' features, for example, domes, walls, ornaments, doors, and pulpits. They were each systematically noted, documented, and compared to systematically identify the application of ethnomathematical concepts.

2.1. Data Collection

Data collection techniques were utilized in the study to get firsthand information regarding the application of ethnomathematical principles in Majid Al-Mashun and Great Mosque of Al-Osmani buildings. Techniques employed are:

2.1.1. Observation

It predominantly employs direct observation of the mosques to identify and record ethnomathematical concepts in their architecture. Researchers examine various aspects such as shapes, form, ornaments, and designs. It provides empirical and true data. At every stage of the observation process, architectural elements such as symmetry, repetition of ornamentation, and proportions of buildings are considered. The objective is to learn the application of mathematical principles in planning and constructing the architecture, including dome contours, flooring designs, door and window placements, and tower constructions. Geometric transformations applied are also achieved through observation and words proven by photographic evidence.

2.1.2. Documentation

Documentation is utilized to support data collection on the visual and historical elements of the mosques. These include photographs, sketches, and observations detailing geometric patterns and architectural elements. The photographs are taken at different angles to ensure complete coverage for ethnomathematical analysis. Documentation in the form of written sources such as archives and research papers is also utilized, providing historical background facts regarding the design and construction process. In-depth descriptions help improved examination of the connection between mosque architecture and ethnomathematics.

2.1.3. Studi Literature

Literature review ratifies observations by looking at books, journals, research articles, and academic journals of ethnomathematics, Islamic architecture, and application of mathematics in building construction. Through this, observations within the field can be juxtaposed with theories to be able to have a strong analytical foundation. Literature review also outlines the historical development of geometric concepts within Islamic architecture and how they were implemented within traditional buildings. Through the balance of theoretical citations and on-the-ground observations, researchers are able to explain the dynamics of mosque construction practices, mathematics, and culture.

2.2. Data Analysis Techniques

2.2.1. Data Reduction

Observation and documentation data at this stage are filtered and grouped in accordance with their relevance to ethnomathematical concepts in the architecture of the mosque. Data that are not relevant are not considered, while data that are significant are summed based on mathematical factors such as geometry, symmetries of patterns, and propositional concepts in mosque architecture.

2.2.2. Data Presentation

Data collected are presented in the form of visual documentation and historical narration in the form of photographs, sketches, and narrative descriptions of geometric patterns and figures. Photos taken from different orientations have sufficient coverage to allow proper analysis of ethnomathematical concepts. Documentation also makes reference to archives and research reports to position mosque design and construction properly historically. The whole presentation allows for proper analysis of the relationship between ethnomathematics and mosque architecture.

2.2.3. Data Conclusion

The final step is where conclusions and analysis of the implementation of ethnomathematics in the studied mosques are drawn. Comparisons between data from the two mosques to find similarities and differences in the implementation of mathematical elements are drawn. Analysis also considers the philosophical as well as the cultural significance of the application of mathematical ideas in the architecture of mosques to promote a better understanding of the nexus between culture, mathematics, and architectural practice.

3. Results and Discussion

3.1. Decryption of Research Objects

Al-Mashun Grand Mosque and Al-Osmani Grand Mosque are two historic mosques that possess exceptional architectural designs and ornaments. Apart from being religious institutions, the mosques enjoy rich cultural backgrounds. The general design of their structures is not only exceptional but also the extremely bespoke ornaments with deep philosophical, religious, and cultural significances.

The building architecture of the Grand Mosque Al-Mashun of Medan is a mixture of European, Middle Eastern, and Asian building styles. The eclectic architecture reflects the cosmopolitan culture environment of the region at the time of construction. Ornaments from life in culture like flower motifs, petal patterns, and geometric shapes adorn the mosque. Each ornament carries Islamic principles with it, including justice, awareness, and harmony, to make the mosque visually appealing as well as symbolically rich.

Meanwhile, Al-Osmani Grand Mosque likewise reflects a design that represents the synthesis of Deli Malay culture and European culture. The ornamentation in the mosque appears in the form of flora, fauna, geometry, and calligraphy. All these ornamentations are found in almost every part of the mosque, ranging from the pillars to the crystal lamps, and give an exquisite aesthetic value to the entire structure. The aesthetic of this ornament contributes to the mosque's beauty in addition to acting as a place of worship and a da'wah center.

In both these mosques, the ethnomathematical aspect is reflected in various geometric elements used in construction and ornamentation design. Starting from the motif domes on the outer walls, floors, mosque poles, doors, and stairs, each element consists of a geometric pattern that can be traced to mathematical concepts like plane construction and constructing space. This is a reflection of how the mosque's design is not just a piece of art but also shows that there is an understanding of the geometry and mathematics used to bring harmony to the building.

3.2. Flat Geometry

A flat geometry is a two-dimensional geometric shape that only has length and width but does not have height (thickness). All the points lie on a single flat plane.

3.2.1. Circle

As observed from Figure 1, stained-glass ornamentation above the Al-Mashun Grand Mosque is circular in nature. This shape not only serves as an ornament but also as a functional aspect, as light enters through from the entrance and travels through to the mosque room. The stained-glass pattern within the circle consists of a symmetrical pattern characteristic of Islamic architecture and represents order and beauty.

Figure 1. Stained-glass ornament of the Al-Mashun Grand Mosque

Figure 2. Roof window of the Al-Osmani Grand Mosque

From Figure 2, the mosque roof window is also circular in shape. This window serves as a natural light source from above, enhancing air circulation in the room. The circle on this window is surrounded by symmetrical floral ornaments that reinforce the aesthetic value. Just like the first image, this circular shape also represents a symbol of perfection and immortality, which is commonly found in mosque architecture.

A circle is a closed curve that has a 360-degree angle with a constant radius size (Rinanto et al., 2013). A circle is a two-dimensional shape formed from a collection of points that are evenly spaced from a single fixed point called a central point. The distance between the centre point and any point on the circle is called the radius. The straight line that connects two points on the circumference and passes through the centre point is called the diameter, which is twice the length of the radius. Circle formula:

Circle Area: $A = \pi r^2$ (1)

Circle Circumference: $K = 2\pi r$ atau $C = \pi d$ (2)

Where A is the area of the circle, r is the radius, C is the circumference, and d is the diameter.

3.2.2. Triangle

From Figure 3, it can be seen that the door of the Al-Mashun Grand Mosque has a geometric motif with a dominance of rhombus shapes and triangular patterns in it. The triangular pattern seems to be symmetrically arranged in each area of decoration. The triangular shape as part of a flat build has a strong, firm, and stable character, which visually gives an impression of regularity and assertiveness to the door design.

Figure 3. Door of the Al-Mashun Grand Mosque

Figure 4. Mimbar ornament of the Al-Osmani Grand Mosque

From Figure 4, it appears that the pulpit of the Al-Osmani Grand Mosque displays wooden ornaments with a clear triangular flat structure on the side of the pulpit. The large upward-pointing triangle possesses the strength to strengthen the feeling of firmness and direction, paralleling the religious meaning in Islam of climbing up to the Most High. The form, besides serving as a structural and architectural element, adds to the symbolism in the place of worship as well.

A triangle is a two-dimensional flat shape formed by three sides and three corners. The three sides are in the form of straight lines that are connected and form three corner points. The number of angles in a triangle is always 180 degrees. Based on the length of their sides, triangles are divided into three types, namely equilateral triangles (all sides and angles are the same), isosceles triangles (two sides and two angles are the same), and arbitrary triangles (the three sides are different in length and the angles are different in size). In addition, based on the magnitude of their angles, triangles can also be classified into right triangles (having one angle of 90°), obtuse triangles (having one angle of more than 90°), and pointed triangles (all of which have angles less than 90°). Triangle formula:

Triangle Area: $A = \frac{1}{2} \times a \times t$ (3)

Circumference of the Triangle: $C = a + b + c$ (4)

where A is the area of the triangle, C is the circumference (perimeter) of the triangle, a is the base length, t is the height measured from the base a, b is the length of the second side, and c is the length of the third side.

3.2.3. Square

From Figure 5, it is evident that the decorative pattern on the wall of the Al-Mashun Grand Mosque is arranged repeatedly in a square design. Each unit of pattern makes a square which connects others symmetrically and in an ordered manner. The repetition of the pattern creates a very distinct visual effect of regularity and demonstrates the use of translation (shift) in geometric transformation theory. Construct a flat square figure, with equal sides and right angles, showing values of equality and harmony. From an ethnomathematical perspective, this cyclical motif is the mathematical order that is infused in Islamic aesthetics and local architectural art, which not only adorns the place of worship but also conveys a message of order and serenity.

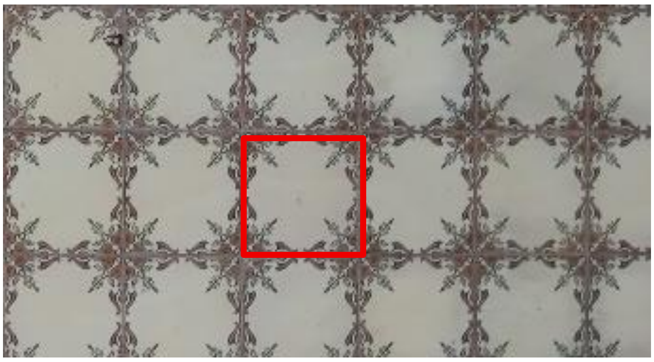

Figure 5. Al-Mashun Grand Mosque wall pattern

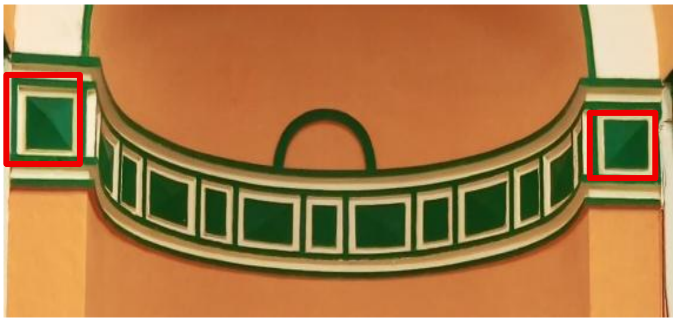

Figure 6. The Pulpit of the Al-Osmani Grand Mosque

As apparent from Figure 5, the decorative design on the wall of the Al-Mashun Grand Mosque is reproduced in a square pattern. The pattern unit is a square that is connected to others symmetrically and in an orderly fashion. The recurrence of the pattern produces a strong visual perception of rhythm and demonstrates the application of translation, or transformation, as a geometric operation. The square four-sided two-dimensional figure with four right angles and sides of equal length is employed to signify equality and balance values. The repeating patterns demonstrate the integration of Islamic design and native architecture art with mathematics. The design elements do more than add beauty to the place of worship; they communicate messages of harmony, order, and peace.

As can be seen in Figure 6, pulpit of Al-Osmani Grand Mosque is adorned with squares in parallel patterns. Here, the squares are utilized as ornaments that provide a clean and symmetrical visual appearance to work towards the effect of stability and orderliness of the pulpit. Other than their visual purpose, the geometric shapes in question possess philosophical connotations, such as justice and steadfastness of values, that complement the pulpit role of being a platform of a speaker for religious and moral instruction. This is one way in which simple geometric shapes can carry deep cultural and religious connotations.

Geometrically, a square is a two-dimensional flat shape with four equal sides and four right angles. All the sides and all the angles are 90 degrees, and hence it is also a regular rectangle. A square also includes two pairs of equal-length parallel sides and two equal-length perpendicular diagonals that meet at the midpoint, so it is symmetrical and balanced. Square formula:

Square Area: $A = s \times s$ (5)

Square Circumference: $C = 4 \times s$ (6)

Where L is the area of the square and s is the length of one side of the square; C is the circumference (perimeter) of the square.

3.2.4. Rectangle

Figure 7. The Pulpit of the Al Mashun Grand Mosque

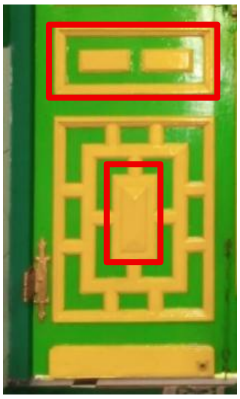

Figure 8. Doors of the Al-Osmani Grand Mosque

As it can be seen from Figure 7, Al-Mashun Grand Mosque pulpit features the prevalence of rectangular shape on the outer wall and decorated panels. The rectangle is not only the prevailing shape of the pulpit, but also an artistic medium in terms of aesthetic expression with the Islamic motifs on it. Rectangles with opposite sides equal in length and right angles make them represent stability and order. Under ethnomathematics, the use of flat forms illustrates the incorporation of geometric properties in religious building construction. The balance and symmetry of this rectangular shape contribute further to increasing the aesthetic and religious value of the pulpit as a platform upon which religious teachings and sermons are preached.

As Figure 8 shows, Al-Osmani Grand Mosque's door consists of two leaves of the same door, and the main decoration is a repetitive and symmetrical pattern in the form of a rectangle. This two-dimensional design offers a functional and simple form and adds aesthetic value to the door. Rectangles are not just employed as the doors' fundamental form, but also as geometrical patterns in their decoration, symbolizing simplicity and order. The form flawlessly suits the mosque's design philosophy, where balance, openness, and aesthetic harmony take precedence. Mathematically, from an ethnomathematical perspective, the employment of rectangular forms illustrates how Islamic architecture's cultural and religious tradition heavily embraces mathematical ideas.

A rectangle is a two-dimensional flat structure that has two sets of sides of equal length and direction, and four right angles (90 degrees each). Unlike a square, only opposite sides of the rectangle are of equal length. It has two diagonals of equal length and bisects each other, but not perpendicularly as in a square. Rectangle formula:

Rectangular Area: $A = p \times l$ (7)

Rectangular circumference: $C = 2 \times (p + l)$ (8)

Where A is the area of the rectangle and p is the length, l is the width of the rectangle, and C is the circumference (perimeter) of the rectangle.

3.2.5. Rhombus

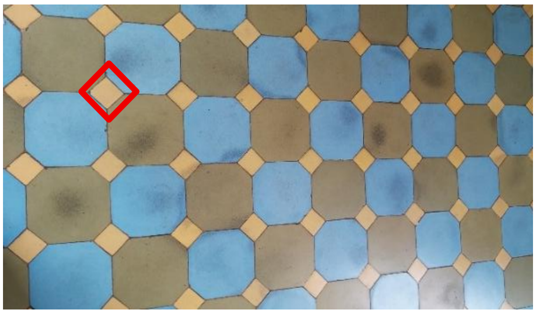

Figure 9. Floor Pattern of the Al-Mashun Grand Mosque

Figure 10. The pulpit of the Al-Osmani Grand Mosque

From Figure 9, the floor pattern of the Al-Mashun Grand Mosque can be seen, which consists of small yellow rhombus shapes filling the spaces between the main tiles. This rhombus is a flat shape with four equal sides and two pairs of opposite angles of equal size. Although it is not the dominant shape, rhombus elements are consistently used as fillers between octagonal flat structures and other rectangles, creating symmetrical and harmonious patterns. Mathematically, this arrangement demonstrates the use of tessellation, translational symmetry, and rotation, which are part of ethnomathematics in Islamic architectural art. This repetition of the geometrical designs not only enhances the beauty of the region but also reflects the regularity and spiritual values embedded in the mosque floor design.

As can be seen in Figure 10, Al-Osmani Grand Mosque's pulpit is ornamented with carved panels that contain an apparent rhombus form in the center of its side. The geometrical shape is visually accentuated by the fact that it has thick framing lines that draw attention and bring beauty to the pulpit. The rhombus has folding and rotational symmetry, and it is a symbol of balance and harmony. Ethnomathematically, this pattern illustrates the application of basic geometrical concepts in carvings to convey cultural and spiritual importance. Additionally, the rhombus demonstrates the use of reflection and symmetry, reinforcing a sense of order and purity within the pulpit space, which serves as a platform for delivering da'wah.

A rhombus is a two-dimensional, flat shape that has four sides of equal length, with a pair of opposite sides of equal length. The defining feature of a rhombus is that its two diagonals intersect at right angles and bisect each other into two equal parts. These diagonals also serve as axes of symmetry. Although all sides are the same length as a square, a rhombus does not always have right angles. Rhombus formula:

Rhombus Area: $A = \frac{1}{2} \times d_1 \times d_2$ (9)

Circumference: $C = 4 \times s$ (10)

Where A is the area of the rhombus, d1 and d2 are the diagonals of the rhombus; C is the circumference (perimeter) of the rhombus, and *s* is the length of one side.

3.2.6. Trapezoid

Figure 11. Inside the dome of the Great Mosque of Al-Mashun

Figure 11 shows the inside of the dome of the Al-Mashun Grand Mosque which is decorated with a trapezoidal plane arrangement arranged in a circular arrangement from the centre of the dome. The trapezoid is a two-dimensional shape with a pair of parallel sides. In this image, the trapezoid is used as decorative panels that form a radial plane surrounding the chandelier in the centre of the dome. Each trapezoid is adorned with symmetrical floral motifs, adding aesthetic and spiritual value to the mosque's interior design. Meanwhile, in the Al-Osmani Grand Mosque, there was no use of trapezoidal shapes that protruded either on the ceiling, dome, or other architectural elements. This is one of the striking differences in the application of flat buildings in the architecture of the two mosques.

A trapezoid is a rectangular flat plane with the characteristics of two parallel sides (Nur et al., 2024). A trapezoid is a two-dimensional flat shape that has four sides, with one pair of parallel sides. These parallel sides are called the top side and the bottom side (or base), while the other two sides are called the trapezoidal legs, which are usually not aligned. Based on the length of the sides and the size of the angles, the trapezoid is divided into several types, namely arbitrary trapezoids, isosceles trapezoids (having the same legs of the same length and the same large base angles), and right-angle trapezoids (having a single angle of 90 degrees). Trapezoid formula:

Trapezoidal Area: $A = \frac{1}{2} \times (a \times b) \times t$ (11)

Circumference of the Trapezoid: $C = a + b + c + d$ (12)

Where A is the area of the trapezoid, a and b are the lengths of the parallel sides, t is the height, and C is the circumference (perimeter) of the trapezoid with sides a,b,c, and d.

3.3. 3D Geometry of Building Space

3D Geometry is a branch of mathematics that studies three-dimensional (3D) shapes that have length, width, and height. Build spaces have volume (content) and surface area, and consist of sides, ribs, and corner points.

3.3.1. Tube

From Figure 12, the pillars of the Al-Mashun Grand Mosque are geometrically tube-shaped, namely a three-dimensional space with two parallel and congruent circular bases and lids, as well as one curved side. These pillars stand vertically and are arranged in parallel, showing symmetry and spatial order. The shape of the tube provides stability and structural strength, as well as a majestic impression of the room. From an ethnomathematical perspective, the use of these tubes shows the community's understanding of the concept of building space, as well as the application of translational symmetry to the placement of neatly arranged poles along the prayer area.

Figure 12. The Pillar of the Al-Mashun Grand Masque

Figure 13. The pillars of the Al-Osmani Grand Mosque

From Figure 13, it appears that the pillars of the Al-Osmani Grand Mosque also use the basic shape of a tube as its primary structure. These tubes are equal in height and width, depicting the concept of symmetry and proportion in geometry. The regular alignment of poles in a single straight line also depicts the application of translation. The form of this tube, apart from serving as a supporting structure, also assists in the beauty of Islamic architecture. In ethnomathematics, the tube form on this pole illustrates how basic mathematical elements are incorporated in the construction of the traditional buildings which are so laden with culture and religion.

A tube is a three-dimensional space structure that has two congruent circular bases (of the same size and shape) and one curved side that envelops the two bases. The distance between the two bases is referred to as the height of the tube. The tube consists of three main parts: the base, the blanket, and the lid (when closed). Tubes include curved side space because their surface is curved, unlike the flat plane of cubes or blocks. Tube formula:

Tube Area: $A = 2\pi r(r + t)$ (13)

Volume Tabung: $V = \pi r^2 t$ (14)

Where A is the surface area of the tube (cylinder), V is the volume of the tube (cylinder), r is the radius of the base, and t is the height of the tube.

3.3.2. Rectangular Prism

Figure 14. The steps of the Al-Mashun Grand Mosque

Figure 15. Steps of the Al-Osmani Grand Mosque

Figure 14 shows the pulpit staircase of the Al-Mashun Grand Mosque which is composed of several steps in the shape of a block. This block room building has six sides in the form of a rectangle, with three pairs of facing sides of the same size. The staircase is decorated with small tubular columns on the sides, adding aesthetic value. Geographically, the arrangement of the rectangular prism-shaped staircase reflects the concept of order and proportionality in building space. In ethnomathematics, the shape of the Rectangular Prism on the steps illustrates the application of the concepts of volume and surface area in the functional structure of architecture, as well as a means to understand basic concepts of spatial geometry in a contextual context.

Figure 15 shows the pulpit staircase of the Al-Osmani Grand Mosque which also uses the shape of a block on each of its steps. All of the blocks are complemented by wooden carvings that reflect traditional Malay delicacies, showing both form and function. Although the form of the design is simpler than that of the Al-Mashun Grand Mosque, the rectangular prism shape is still employed as the basic structure. From an ethnomathematic perspective, the building form of the rectangular prisms for these steps illustrates how basic forms are applied in everyday life, namely in religious structure design.

A Rectangular Prism is a three-dimensional space built by six sides in the form of a rectangle. The Rectangular Prism has 12 ribs, 6 sides, and 8 corner points. The three pairs of sides facing each other on the Rectangular Prism are of the same shape and size, and each angle is a right angle (90 degrees). The sides of the Rectangular Prism consist of length, width, and height. Rectangular prism formula:

Rectangular prism Surface Area: $A = 2 \times [(p + l) + (p + l)(l + t)]$ (15)

Rectangular prism Volume: $V = p + l + t$ (16)

Where L is the surface area of the rectangular prism (cuboid), V is the volume of the rectangular prism (cuboid), p is the length, l is the width, and t is the height

3.3.3. Cube

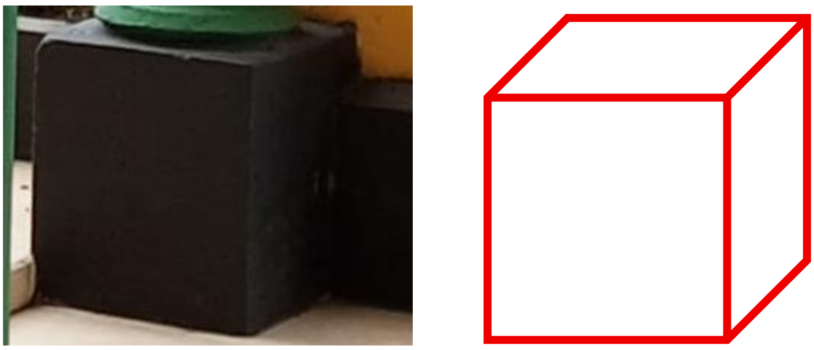

Figure 16. The pillars of the Al-Osmani Grand Mosque

Figure 16 shows the bottom of the pillars of the Al-Osmani Grand Mosque which uses the shape of a cube as the base of the pillar. Mathematically, the use of the cube shape at the bottom of the pole shows the application of the concept of spatial geometry which has high regularity and balance in terms of size and symmetry. The cube symbolises the stability and perfection of form, which aligns with Islamic values of balance in creation.

Meanwhile, in the Al-Mashun Grand Mosque, there was no use of a prominent cube shape on the poles or other structural elements. The pillars in the mosque are directly cylindrical from the bottom to the top without a cube-shaped base. This difference is one of the characteristics of each mosque in terms of the application of building space in their architectural design.

A cube is a three-dimensional spatial structure that has six sides that are square, with the same length on all sides. The cube also has 12 ribs of equal length and 8 corner points. All angles on the cube are right (90 degrees), and each side is perpendicular to the other. Cube formula:

Cube Area: $A = 6 \times s^2$ (17)

Cube Volume: $V = s \times s \times s$ (18)

Diagonal lenght: d= $s\sqrt{3}$ (19)

Where A is the surface area of the cube, V is the volume of the cube, d is the space diagonal of the cube, and s is the length of one side.

3.3.4. Half-sphere

From Figure 17, it can be seen that the dome of the Al-Mashun Grand Mosque is in the shape of a semisphere (hemisphere) which is part of the shape of the sphere geometry space. This half-sphere shows a symmetrical curved structure and symbolizes perfection and integrity in Islamic architecture. The shape of the half sphere reflects rotational symmetry on its vertical axis and possesses radial symmetry, where each point on the surface of the dome is equidistant from the central point of the base.

This dome also shows translation in the pattern of its supporting structure such as pillars around the base of the dome that are arranged repeatedly and parallel. Application of the half-sphere form as the dominant roof of the mosque is not only an issue of beauty value, but it is also a reflection of unity and order, two implicit concepts in ethnomathematics derived from Islamic religious and cultural values.

As indicated by Figure 18, the dome of Al-Osmani Grand Mosque itself employs a similar half-sphere shape, albeit with simpler dimensions and an elaborate design. The construction of this dome continues to display radial symmetry as well as rotational symmetry, pointing out that this geometric shape was chosen not only for its beauty but also due to its philosophical connotations.

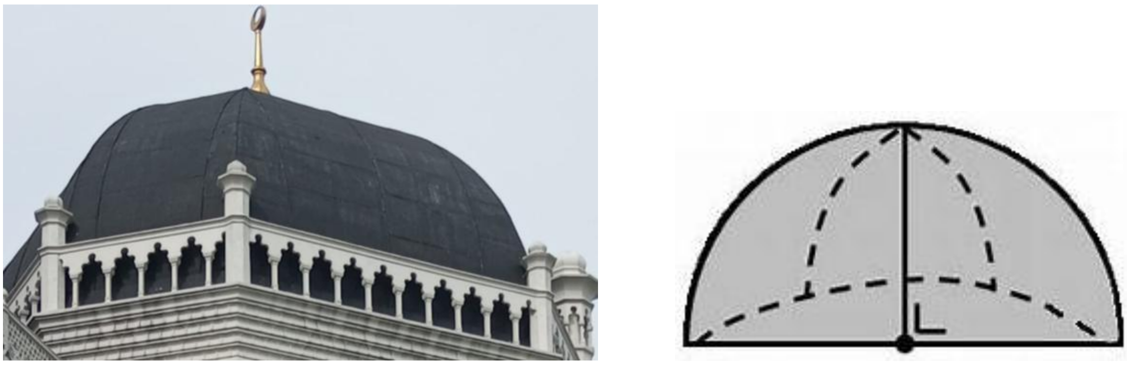

Figure 17. Dome of the Al-Mashun Grand Mosque

Figure 18. Dome of the Al-Osmani Grand Mosque

The main difference lies in the exterior appearance of the dome: while the Al-Mashun Grand Mosque has vertical ornaments on the rim of the dome, the Al-Osmani Grand Mosque appears sterner, with a general impression of looking clean and light to the eyes. However, both reflect ethnomathematical concepts, in which the shape of a semi-sphere is used to symbolize the oneness of God, the perfection of creation, and the vast spiritual horizon, harmoniously combined with the sacred function of the worship space.

A half-sphere, also called a hemisphere, is a three-dimensional space structure that is half of the whole sphere. This shape has only one curved side (half of the ball's surface) and one circular base. Half-sphere formula:

Surface Area of a Base Half Ball: $A = 2\pi r^2$ (20)

Surface Area of Half Ball with Base: $A = 3\pi r^2$ (21)

Half Ball Volume: $V = \frac{1}{2} \times \frac{4}{3}\pi r^3 = \frac{2}{3}\pi r^3$ (22)

Where A is the surface area, V is the volume, and r is the radius of the half ball (hemisphere).

3.4. Geometry Transformation

Geometric transformation is a process of moving or changing the position of a geometric shape to another location in a plane or space, following specific rules.

3.4.1. Reflection

Figure 19. The window of the Al-Mashun Grand Mosque

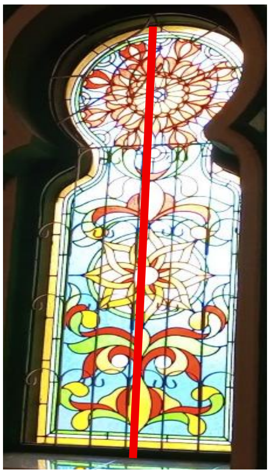

Figure 20. Window of the Al-Osmani Grand Mosque

From Figure 20, the windows of the Grand Mosque of Al-Osmani also feature a vertical shape with a distinctive arch at the top, but the design is more complex with a shape resembling a door lock on the frame. The stained-glass is decorated with floral motifs full of red, yellow, green, and blue colors that are arranged symmetrically against the vertical centerline. Reflections are clearly visible in the repetition of shapes and colors on the left and right sides. In addition to reinforcing the visual aspect, this symmetry is part of the symbolism of perfection in Islamic culture, where the regularity of form reflects the regularity of God's creation.

The result of the reflection is a mirror image of the original building. The distance of each point on the waking to the reflection line is equal to the distance of the reflection point to that line, and the reflection result wakes are congruent with the original waking (Taneo et al., 2025). Geometric reflection is a transformation that moves each point on a figure into a mirror image across a certain line, known as the axis of reflection. In this process, the distance between the point and the reflection axis is always equal to the distance of the shadow to that axis, ensuring that the shape and size of the building remain unchanged. The difference that occurs is only in the orientation of the building which becomes inverted, like an object seen on the surface of a mirror. For example, if a point (x, y) is reflected against the y-axis, then its shadow will be at the point (−x, y).

3.4.2. Translation

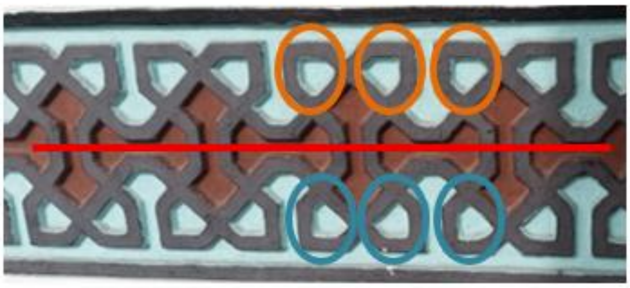

Figure 21. Geometric wall ornament of the Al-Mashun Grand Mosque

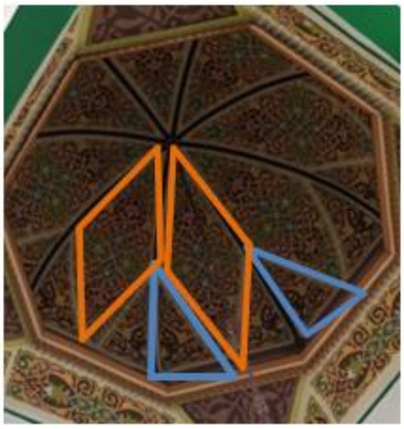

Figure 22. Inner dome ceiling of the Al-Osmani Grand Mosque

From Figure 21, the geometric ornaments of the walls of the Al-Mashun Grand Mosque show a pattern that is repeated regularly through the concept of translation. The basic shape is in the form of an angular pattern with a combination of brown, black, and light blue colors arranged in a horizontal row with the same distance and orientation. This repetition creates the illusion of a continuous visual rhythm, based on the principle of regularity in geometry. The interlocking configuration among the elements represents the cohesion of the composition, which can be represented mathematically as a reproduction of the vector in a two-dimensional plane.

As can be observed in Figure 22, the ceiling of the inner dome of the Al-Osmani Grand Mosque translates the principle but in circular form. Decorative motifs composed of curved symmetrical motifs are repeated periodically on all segments of the plane of the dome. Although the arrangement forms a rotational pattern, each segment has the same ornamental element so that if straightened, it can be understood as the result of repeated translation. The use of contrasting colours, such as green, red, gold, and black, strengthens the reading of the pattern while adding a harmonious aesthetic dimension to Islamic architecture.

Translation (shift) is a type of geometric transformation that focuses on the shift of a certain object from a point in a certain direction and distance (Aprizal & Karlina, 2025). Translation is a form of geometric transformation that moves each point on a building the same distance and direction, without changing its shape, size, or orientation. This movement is carried out in parallel, so that all points on the body move in a uniform direction and with a uniform distance. The result of the translation will produce a wake that is identical to the original wake, only different in its position in the field. For example, if a building is shifted a few units to the right or up, then all points on the building will follow a shift of the same distance, so that its shape remains unchanged.

3.4.3. Rotation

Figure 23. Inner dome ceiling of the Al-Mashun Grand Mosque

Figure 24. Stained-glass in front of the door of the Al-Mashun Grand Mosque

As shown in Figure 23, the inner dome ceiling of the Al-Mashun Grand Mosque features a regular rectangular base, arranged symmetrically around the dome's central point. Each plane is adorned with repeated ornamental patterns set at specific angles, reflecting the concept of rotation around the dome's center. This design creates a sense of visual harmony and mathematical harmony and works towards emphasizing the architectural purpose of the dome to lead the viewer's eye upward. Ethnomathematically, the plan represents ideas of beauty, balance, and order as central components of Islamic values in architecture.

Figure 24 is the entrance stained-glass window in Al-Osmani Grand Mosque with a circular flower design in a symmetrical pattern revolving around its centre. Every petal is in the same rotational position, and hence the whole pattern is symmetrical from every viewing point. Visual contrast is provided by using vivid colours such as red, yellow, green, and blue to define the rotational position. In the ethnomathematical context, not only does this pattern decorate the mosque, but it also symbolizes the order, completeness, and sophistication that are at the root of Islamic cultural beauty.

Geometrically, rotation is a motion that translates all the points of an object in a circular motion from a fixed point called the center of rotation (Fife et al., 2019). The distance between each point and the center remains unaltered upon rotation, but it maintains the shape and size of the object while changing its location. For example, turning a figure 90 degrees counterclockwise from the point of origin (0,0) moves all points along a circular arc, maintaining a constant radius from the center. This supports rotational symmetry of the stained glass and dome patterns, demonstrating how mathematics is used to apply to art and cultural forms.

The outcome of this research indicates that Al-Mashun Grand Mosque and Al-Osmani Grand Mosque both have very high applications of ethnomathematical concepts, specifically geometry and geometric transformations. As indicated in Figures 1–24, it is evident that there are many geometric shapes, including circles, semicircles, isosceles triangles, squares, rectangles, rhombuses, trapezoids, and tubes, that are implemented on architectural elements, including domes, windows, doors, ceilings, columns, pulpits, and floors. These uses are contrasted more fully in Table 1. Beyond their beauty, the geometric patterns herein hold deep symbolic significance that speaks to the cultural values and religious aspirations inherent in the design of each mosque.

Table 1. Comparative Analysis of Ethnomathematical Concepts in Al-Mashun and Al-Osmani Mosques

Indicator	Al-Mashun Grand Mosque	Al-Osmani Grand Mosque
Basic 2D Geometric Shapes	• Circles in stained glass • Octagonal base structure • Triangular and rhombus motifs on doors/floors • Squares and rectangles in wall ornaments	• Circles in windows • Rectangular base structure • Triangular motifs in pulpit ornaments • Rhombus carvings on panels • Floral–geometric combinations
3D Geometric Solids	• Blocks in staircases • Cylindrical/tube-shaped columns • Hemisphere dome with ornamental patterns	• Cubes at column bases • Cylindrical/tube-shaped columns • Hemisphere dome with simpler design
Geometric Transformations	• Reflection in stained glass motifs • Translation in repeated wall/floor ornaments • Rotation in dome ceiling patterns	• Reflection in window symmetry • Translation in radial ceiling ornaments • Rotation in floral stained-glass motifs
Dominant Structural Form	• Octagonal and symmetrical • Strong Middle Eastern & Mughal influence	• Rectangular and elongated • Strong Malay, Chinese & European influence
Ornamental Characteristics	• Complex stained glass and arches • Intricate ornamental details	• Bright-colored floral motifs • Calligraphic and simpler designs
Cultural Integration	• Blend of Malay, Arabic, Indian, and Spanish influences	• Blend of Malay, Indian, Chinese, and European influences

The same is the pattern used in international studies. Iranian and Central Asian mosques have been observed by Azari et al., (2023) to frequently incorporate polygonal star motifs and rotational symmetry in building designs and elements, all of which reflect a mathematical order that is very much Islamic art. The application of the octagonal shape and rotational symmetry in Al-Mashun Grand Mosque strictly follows the pattern. Conversely, the Al-Osmani Grand Mosque uses floral as well as geometric motifs, demonstrating the syncretic methods used in Southeast Asia, where Islamic geometry was combined with foreign elements like Chinese and European.

In general, the Al-Mashun Grand Mosque primarily derives from symmetrical and orderly geometric shapes, emphasizing regularity and purposeful rotation symmetry. This is seen in the alignment of windows, ceiling ornamentation, and floor designs, which are all demonstrating form consistency and measurement. Al-Osmani Grand Mosque, however, introduces flower forms to complement geometric shapes to produce a distinctive piece demonstrating multiplicity of forms. In spite of the variation in their visual attractiveness, both mosques indicate the use of mathematical theories in the achievement of harmony and visual balance through repeated repetition of symmetry, order, and proportion. As Kadoi & Masuya (2017) noted in their article on the Topkapı Scroll, strict geometric treatises were utilized as the basis for mosque design in Timurid–Safavid Iran. The austere and exacting geometry of the Al-Mashun Mosque suggests compliance with formal order like this, whereas that of the Al-Osmani Mosque suggests adaptive cultural practice, with geometry blending with floral and calligraphic motifs in loose combinations.

In the cultural and historical perspectives, Al-Mashun Grand Mosque is a blend of Middle Eastern, Indian, and European architectural forms. Al-Osmani Grand Mosque, however, owes a great debt to Deli Malay architecture but draws influences from Arabic and Chinese cultures. These cultural influences gain priority in deciding the choice of geometric shapes and motif ornamentation. From an ethnomathematical perspective, not only are they aesthetically pleasing; they are also a vehicle for the storage and expression of the inherent cultural values within the architectural structure of the mosque.

Cross-cultural ethnomathematical research backs this case. Iskandar et al., (2022), in a systematic review of Indonesian and global cases, mentioned that the geometric forms are always adapted using native material and designs and highlighted that mathematics in architecture can never be exclusively cultural. This vindicates the notion that the Al-Mashun and Al-Osmani mosques, even though founded on the same geometric notions, realize mathematics in such a way as to promote local identity and heritage.

These findings are of great importance to mathematics education, particularly to such topics as geometry and geometric transformations. Through the use of these mosques as contextual models, students will be able to conceptualize that mathematical concept are beyond the book, in the immediate surroundings and heritage culture. This exercise can also encourage students to learn, apply, and value mathematics more as part of day-to-day life.

4. Conclusion

Both mosques have a wealth of geometric shapes and a strong application of mathematical principles. Basic shapes, such as cubes, semispheres, circles, squares, rectangles, triangles, and regular polygons, are commonly found in columns, domes, windows, ceilings, floors, and wall ornaments. The principle of geometric transformation is also clearly visible, where reflection is seen in stained-glass motifs and wall decorations, translation (shift) is seen in the repetition of geometric ornamental motifs, and rotation is dominant in the design of dome ceilings and stained-glass motifs in the shape of flowers or stars. All these forms and structures not only perform a beauty function but also carry philosophical meanings and Islamic cultural values that emphasize harmony, unity, and order.

With reference to the research objectives, the research has established that: (1) the Al-Mashun Grand Mosque reflects ethnomathematical principles primarily in octagonal structures, symmetrical patterns, and complex ornamenting details drawn from Mughal and Middle Eastern architectural designs; (2) the Al-Osmani Grand Mosque reflects ethnomathematical principles through rectangular structures and floral, geometric interplays drawn from Malay and European architectural designs; and (3) the comparison identifies both similarity in the uses of basic shapes and transformations, and distinct cultural adaptations found in their ornaments and pattern configurations. Thus, one can boldly say that these two mosques are proof of the close relationship among mathematics, art, and architecture, whereby their geometry and transformation not only decorate the structures but also maintain the visual identity and religious meaning passed down from generation to generation.

For future research, it is recommended that the same comparative study on other religious or cultural buildings, such as churches, temples, or indigenous houses, be conducted to observe more of how ethnomathematical principles manifest across cultures. Additionally, interdisciplinary approaches that combine mathematics, history, and cultural studies can tell us more about how geometry is involved in the preservation and transmission of cultural identity.

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