

MATHEMATICS IN CULTURAL HERITAGE: AN ETHNOMATHEMATICAL ANALYSIS OF THE ARCHITECTURE OF FORT ROTTERDAM

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Abstract

This study analyzes the application of ethnomathematics in Fort Rotterdam, Makassar, focusing on the use of numbers and measurements in architecture as symbolic representations and defense strategies. The research employed direct observation, semi-structured interviews with tour guides, and literature review of supporting documents and journals. The findings indicate that numbers are utilized in various mathematical activities, including counting the number of bastions, gates, and internal buildings; measuring the length, area, height, and wall thickness; and designing structures that serve both strategic functions and cultural meanings. Notably, the five bastions were designed to resemble a turtle, reflecting the Gowa Kingdom's philosophy of ruling over both land and sea. The implications of these findings are significant for mathematics education, as integrating local cultural contexts and symbolism into learning can enhance conceptual understanding, problem-solving skills, learning motivation, and students' cultural identity. The study underscores that cultural heritage sites such as Fort Rotterdam are not merely historical artifacts but also serve as contextual mathematics learning resources that enrich formal educational experiences.

Keywords: Ethnomathematics, Fort Rotterdam, Architecture, Numbers, Contextual Mathematics Learning

A. Introduction

Mathematics is often considered a highly abstract discipline, detached from cultural contexts and everyday life. However, through the ethnomathematical approach, it can be seen that mathematics is not merely numbers and formulas on paper, but also reflects the way of life, values, and cultural heritage of a community (D'Ambrosio, 2001 in ethnomathematics literature). Ethnomathematics emphasizes that each culture has its own way of understanding, applying, and interpreting mathematical concepts, both in daily activities and in cultural artifacts (Gerdes, 1996).

In the context of traditional architecture and cultural heritage, building structures often contain hidden mathematical values. Research in Indonesia shows that traditional buildings, monuments, and other architectural objects incorporate geometric concepts, measurements, symmetry, and mathematical transformations expressed in their design and physical construction. For example, research on the Gapura Pramuka at Universitas Muhammadiyah Prof. Dr. Hamka revealed the presence of geometric forms such as triangular pyramids, trapezoids, rectangles, parallel lines, and geometric transformations within the architectural elements of the gate. Similarly, studies on the Simpang Lima Gumul Monument identified planar (rectangular) and spatial (cube) elements as part of the monument's structure. Other studies, such as on Masjid Raya Tanjung Pauh Hilir Kerinci, show that the mosque's ornaments and architectural forms reflect various mathematical concepts, including ellipses, rhombuses, circles, transformations, and spatial geometry.

Moreover, research on the Batak Toba traditional house (Rumah Bolon) in Samosir identified geometric objects integral to the house's design, such as flat geometric surfaces. Studies on the architecture of Masjid Raya Sumatra Barat also reveal the use of planar and volumetric geometric forms (squares, trapezoids, cubes) in the mosque's structure. A more systematic study by Puspitasari & Putra (2022), through a literature review of temple buildings, found that geometric concepts are among the most frequently occurring mathematical concepts in traditional Indonesian temples.

Fort Rotterdam in Makassar, also known as Benteng Ujung Pandang, is one of the historical architectural heritage sites in South Sulawesi that has strong potential for ethnomathematical study. The fort's structures—walls, towers, spatial layout, and proportions—most likely contain carefully designed mathematical values. Similar to previously studied traditional buildings in Indonesian national journals, Fort Rotterdam can also be analyzed from the perspective of geometric forms (shapes, symmetry), measurement and proportion, and geometric transformations.

In addition to architectural aspects, the historical dimension of Fort Rotterdam—as the center of power of the Gowa Kingdom—includes calendar systems, royal succession orders, and records of significant events. These aspects

reflect the use of ordinal and cardinal number concepts in local historical documentation. Therefore, ethnomathematics provides an appropriate framework for investigating how number and geometric concepts are not only applied in the fort's physical design but also in the historical and social documentation of the Gowa community.

Based on this background, the objectives of this study are: (1) to identify and describe number and geometric concepts used in the architecture of Fort Rotterdam (proportions, measurements, symmetry, transformations, etc.); (2) to uncover the application of ordinal and cardinal number concepts in the fort's historical records, including royal succession, major events, and calendar systems; and (3) to analyze how these mathematical concepts relate to the social, cultural, and historical values of the Gowa community, as well as their implications for contextual mathematics education (ethnomathematics).

This study is expected to contribute in several ways: (1) Academically: enriching the ethnomathematics literature in Indonesia with a focus on historical fort architecture, which has received relatively less attention compared to studies on traditional houses or monuments; (2) Educationally: providing a key reference for mathematics education, particularly in developing contextual learning that connects mathematical content with local cultural heritage; and (3) Culturally: supporting the preservation of Fort Rotterdam's heritage by highlighting its mathematical dimensions, allowing the local community and future generations to appreciate its cultural value from both mathematical and historical perspectives.

B. Method

This study employs a descriptive qualitative approach, focusing on the ethnomathematical analysis of the architecture and history of Fort Rotterdam. Data were collected using three main methods: observation, interviews, and literature review. Each method was used complementarily to obtain a comprehensive understanding of the application of mathematical concepts within the local cultural context.

1. Observation

The observation method employed in this study was direct observation, conducted on-site at Fort Rotterdam, Makassar. Observations were carried out systematically and in detail to identify:

1. Architectural forms and building structures.
2. Dimensions, measurements, and proportions of the buildings.
3. Numerical and symbolic elements related to mathematical concepts, including symmetry, ratios, and geometric patterns.

Data obtained from these observations were subsequently analyzed to explore the relationship between the mathematical elements applied and the cultural values and philosophies embedded in the fort's design. Observations involved field notes, physical measurements, and photographic documentation.

The research object was the Fort Rotterdam complex as a whole, with a focus on:

1. The fort's architectural structure and forms, including bastions, walls, gates, and internal buildings.
2. Physical dimensions and measurements of the buildings.
3. Numerical and chronological data related to the fort's history, such as the sequence of construction and significant historical records.

2. Interview

Interviews were conducted using a semi-structured approach, which involved a set of prepared guiding questions while allowing respondents the freedom to provide more in-depth explanations. The interviews aimed to complement observational data and to obtain qualitative information regarding the historical, symbolic, and cultural meanings of Fort Rotterdam's architecture.

The interview subjects were tour guides at Fort Rotterdam who possess extensive knowledge about the history, functions, and symbolic significance of the fort's buildings. The information obtained was used to interpret field data, particularly regarding numerical aspects, chronology, and local philosophies embedded within the fort's structures.

3. Literature Review

In addition to observation and interviews, this study employed literature review to support the analysis and validate the findings. The literature review involved examining, analyzing, and synthesizing information from various written sources relevant to architecture, history, and ethnomathematics.

C. Result and Discussion

This study produced findings illustrating the application of mathematical concepts in the architecture and history of Fort Rotterdam, Makassar. Data obtained through direct observation, semi-structured interviews, and literature review were analyzed to identify mathematical patterns, physical dimensions, and numerical symbolism embedded in the fort's design.

1. Domain: Architecture & Construction



Figure 1. Layout of Fort Rotterdam, Makassar <https://lagaligo-disbudpar.sulselprov.go.id/>

In the domain of architecture and construction, this study emphasizes the quantity of building elements as mathematical representations embedded in Fort Rotterdam. Key findings include:

Number of Bastions: The fort has five bastions, which symbolically and philosophically represent the anatomy of a turtle—one as the head and four as the limbs. This design is associated with the *Penyu* (Panynyua) philosophy, symbolizing the vision and authority of the Gowa Kingdom across two realms, land and sea. Thus, these architectural elements serve not only defensive functions but also convey symbolic and cultural values.

Number of Exits: There are two exits—one main gate on the west side and a smaller gate on the east side. These gates serve practical functions while also

reflecting the fort's strategic layout and spatial organization, which can be analyzed through mathematical concepts of quantity and proportion.

Number of Internal Buildings: The fort contains fifteen internal buildings, comprising fourteen Dutch colonial structures and one Japanese building. This numerical distinction reflects historical classification, marking two different periods of rule. From an ethnomathematical perspective, the use of numbers here serves to differentiate historical and cultural contexts within the fort's structure.

Number of Floors: Internal buildings vary between one, two, and three floors, illustrating the use of height differentiation as an applied mathematical concept in architecture, such as proportion and scale.

Overall, these quantitative elements not only fulfill technical and defensive functions but also express local philosophy and cultural values. For instance, the Penyu philosophy integrates the biological form of the turtle with symbols of power and protection, while the classification of internal buildings reflects historical chronology and changes in colonial influence.

Within the Fort Rotterdam complex, there are fifteen buildings, with fourteen Dutch structures and one Japanese structure. According to a tour guide, "There is one building that is different, the Japanese building. Japan controlled this fort from 1942 to 1945. That is why they built one building." The numbers 1, 14, and 15 are not merely statistical figures; from an ethnomathematical perspective, they are used in counting activities that function as tools for historical classification. Numbering and quantifying buildings allow researchers and the community to distinguish architectural heritage according to historical periods, specifically between Dutch colonial influence and Japanese occupation. Thus, the quantity of buildings functions not only as physical data but also as a mathematical representation of chronology and socio-historical change, integrating numerical aspects with cultural and historical values.

Most buildings within the complex have two to three floors, except for a single Japanese building with only one floor. Based on direct observation and supporting literature, this building is located at the northern end of the eastern row, near the Mandarsyah bastion, and was constructed during the Japanese administration in South Sulawesi in 1942. From an ethnomathematical perspective,

quantifying the number of floors serves as a mathematical attribute used to differentiate architectural styles and historical periods. The numbers indicating floor counts help identify differences in function, needs, and construction contexts between the Dutch and Japanese eras at the same location. In other words, the use of numbers here is not only technical or structural but also carries historical and cultural meaning, serving as a tool to classify and understand architectural transformations over time.

The Fort Rotterdam complex has a total area of approximately 28,595.55 square meters, or roughly three hectares. Its dimensions were strategically designed to align with geographic positions and defense needs during its construction. From an ethnomathematical perspective, precise area calculations demonstrate the application of advanced mathematical principles in measuring activities. Accurate measurements served not only technical construction and defense purposes but also reflect the local community's ability to apply quantitative and precise mathematical concepts within a social and cultural context. Thus, the fort's dimensions and measurements are indicators of mathematics applied in real-life practices, closely linked to architectural strategy and historical value.

The height of the fort's walls ranges from 5 meters (lowest) to 7 meters (highest). According to tour guides, this variation was likely adjusted to the natural terrain and to maximize strategic defense advantages. The variation in height indicates that measuring activities considered natural factors, ensuring the fort was not only structurally strong but also strategically positioned to defend against potential attacks.

The average thickness of the fort's walls is 2 meters, while the internal building walls range from 0.8 to 1 meter. Tour guides explained that the thickness of the outer walls was a standard defense measure at the time, specifically designed to withstand cannon fire. Measuring was applied differently based on risk and function: outer walls for military defense were constructed much thicker, while internal walls were proportioned according to functional needs.

From an ethnomathematical perspective, the variation in wall height and thickness illustrates the application of applied mathematical principles in defensive architecture, including precise dimension calculations, proportional comparisons,

and adaptations to environmental conditions. The numbers used are not merely physical measurements but also serve as strategic and symbolic representations of the technical capabilities of the local community at the time of the fort's construction.

1. Componential Analysis

In the architecture and design of Fort Rotterdam, numbers serve multiple functions, ranging from symbolic, functional, to structural purposes. The componential analysis indicates that the use of numbers goes beyond mere measurement and serves as a medium for cultural representation and strategic planning.

a. Numbers as Symbolic Representation (Natural Numbers)

The five bastions of the fort result from counting activities imbued with deep cultural meaning. Based on observational and interview data, the number five was deliberately applied during the designing process to represent the anatomy of a turtle: one as the head and four as the limbs. This numerical symbolism functions as a mathematical language to convey the philosophy of the Gowa Kingdom, emphasizing power over both land and sea. Hence, simple natural numbers act as cultural symbols integrating mathematics with local values.

b. Numbers as Functional Scale Determinants

The uneven lengths of the fort walls—225 m, 193.2 m, and 164.2 m—demonstrate that measuring activities were not based on regular polygonal geometry. Instead, measurements were guided by pragmatic defense functions, adapted to the geographic contours of the promontory. This numerical variation confirms that strategic needs were prioritized over symmetry, making numbers serve as determinants of functional scale in defensive architecture.

c. Numbers as Classifiers

The total of 15 internal buildings, comprising 14 Dutch-era and 1 Japanese-era structure, illustrates the use of numbers for classifying objects based on historical period and function. Mathematically, these ratios (14/15 and 1/15) represent the proportions of heritage from two distinct historical eras. Thus, numbers serve as historical classification tools, helping to distinguish the temporal and functional context of each building.

d. Numbers as Measures of Thickness and Volume (Decimal Numbers)

The difference in wall thickness between the fort's outer walls (2 m) and internal buildings (0.8–1 m) reflects the application of measuring concepts tailored to function. The outer wall thickness represents a mathematical measure designed for military defense, capable of withstanding cannon fire, whereas the internal wall thickness suffices for civil structural needs. This variation shows how decimal numbers are used with precision to meet distinct functional requirements while maintaining the fort's integrity and effectiveness.

2. Taxonomy

Ethnomathematical analysis at Fort Rotterdam reveals that numbers are employed in activities encompassing counting, measuring, and designing, each playing a significant role in integrating mathematics with cultural values and strategic functions.

a. Counting

Counting activities determine the number of physical elements, such as five bastions, two gates, and fifteen internal buildings. This activity represents the use of natural numbers to quantify objects concretely. Beyond the quantitative function, counting carries symbolic and historical meanings—for instance, the bastion count represents the anatomy of a turtle (1 head and 4 limbs), symbolizing the philosophy of the Gowa Kingdom.

b. Measuring

Measuring activities are evident in the use of meters to calculate the total area of the fort (28,595.55 m²), wall lengths (225 m, 193.2 m, 164.2 m), and wall thicknesses (2 m for outer walls, 0.8–1 m for internal walls). These activities demonstrate the application of quantity and mathematical precision in planning and construction, aligning design with terrain contours and defensive needs.

c. Designing

In designing activities, numbers and measurements are used to create forms that fulfill both defensive functions and symbolic meanings. For example, the placement of the five bastions forms a turtle-like pattern. The use of numbers in design is not solely for technical purposes but also acts as a mathematical language to express cultural values, philosophy, and defensive strategy.

Overall, these three activities demonstrate that numbers at Fort Rotterdam serve multidimensional purposes: as quantitative tools, symbolic representations, and strategic instruments, integrating mathematics with cultural context, historical significance, and the practical functions of defensive architecture.

3. Cultural Theme: Symbolism and Strategic Adaptation

Ethnomathematical analysis of Fort Rotterdam reveals that the use of numbers and mathematical principles is not merely technical but also carries cultural and symbolic meaning.

a. Symbolism and Cultural Vision

This fort demonstrates that mathematics can serve as a language to express a civilization's vision. The use of the number 5 for the bastions and the number 2 representing two realms (land and sea) in the turtle philosophy (Panynyua) reflects how the Gowa community communicated their aspiration to wield power over both land and sea. Thus, mathematics here functions as a symbolic medium that integrates numbers, architectural forms, and cultural values into a single conceptual whole.

b. Strategic Adaptation and Pragmatism

Beyond symbolism, the application of mathematics in the fort also reflects a pragmatic culture. The asymmetrical design of the fort, variations in wall lengths and heights, and wall thickness adjusted according to defensive function indicate that the builders prioritized strategic effectiveness and adaptation to environmental conditions over rigid geometric rules. This approach affirms that mathematics was used as a practical tool for survival while simultaneously serving to realize defensive strategies and symbols of authority.

Overall, the cultural theme at Fort Rotterdam illustrates a combination of symbolism, strategy, and mathematics, where numbers and measurements function not only as technical instruments but also as representations of cultural values and the historical vision of the Gowa people.

Ethnomathematical findings from Fort Rotterdam, such as the use of numbers in symbolic design (e.g., five bastions representing a turtle) and structural measurements, present significant potential for developing more contextualized mathematics learning. Integrating local values and cultural philosophy into

instruction can help students perceive mathematics not merely as abstract concepts but as something rooted in community heritage. This aligns with findings that integrating ethnomathematics into the curriculum can strengthen local culture and make mathematics learning more meaningful.

Furthermore, this approach can support teaching models such as Problem-Based Learning (PBL) with an ethnomathematical orientation. As demonstrated by Antara, Agustini, and Sudata (2024), ethnomathematics-based PBL can improve students' conceptual understanding and problem-solving skills by linking real-life problems from local culture. By presenting contexts like the structure of Fort Rotterdam, students can understand concepts of geometry, measurement, and numbers through real-world problems that also carry historical and symbolic significance.

Another implication is the strengthening of students' cultural identity through mathematics learning. When students learn about the turtle symbol in the fort's design and its meaning, they not only study mathematics but also appreciate Gowa's local history and philosophy. Studies on cultural heritage in Indonesia show that integrating ethnomathematics helps reinforce students' identity and mathematical literacy. Thus, mathematics learning becomes a means of cultural preservation, not merely teaching concepts.

Additionally, embedding cultural heritage—such as regional monuments or traditional artifacts like Fort Rotterdam—into mathematics instruction can significantly enhance students' motivation, engagement, and sense of ownership (Ashari & Alimuddin, 2024). This approach is strongly aligned with Culturally Relevant Pedagogy (Ladson-Billings, 1995), Funds of Knowledge (Moll et al., 1992), and Situated Learning Theory (Lave & Wenger, 1991), which all emphasize the importance of connecting academic content to students' lived cultural experiences.

Empirical studies conducted in Indonesia between 2023 and 2025 provide robust support: for example, Sari, Nisa', As-salamah, & Maharani (2024) used Menara Kudus architecture to develop digital worksheets that improved students' mathematical connections; Susanti, Gunansyah, & Nasution (2025) integrated the traditional headgear Udeng Pacul Gowang into primary mathematics learning,

leading to higher student interest and motivation; meanwhile, Ramalisa, Falani, & Pasaribu (2024) developed and validated a mathematics test based on Jambi cultural concepts, demonstrating reliability in cultural-context assessments; Usman & Rahman (2024) explored mathematical reasoning through the traditional Rumah Gadang architecture, revealing socio-cultural dimensions of number and space in a heritage context; finally, Deda & Disnawati (2024) investigated traditional games in the Indonesia–Timor Leste border region, showing how local game mechanics can preserve culture while facilitating mathematical thinking.

These findings substantiate Rua, Fono, and Wewe's (2025) claim that ethnomathematics-based learning—when rooted in familiar cultural heritage—helps students internalize mathematics as part of their identity. Consequently, they feel that mathematics “belongs” to their culture, which boosts engagement and motivation. This culturally grounded approach not only supports conceptual understanding but also fosters a sense of belonging and personal relevance in students (Ashari & Alimuddin, 2024; Sari et al., 2024; Susanti et al., 2025; Ramalisa et al., 2024; Usman & Rahman, 2024; Deda & Disnawati, 2024). Finally, these findings emphasize the importance of teacher training in developing contextual teaching materials based on cultural heritage. Teachers need to be equipped with an understanding of how to interpret architectural elements such as bastions, walls, and fort structures from both mathematical and cultural perspectives. Teachers trained in ethnomathematics can design learning activities that combine measurement, design, and symbolism, bridging local knowledge with formal mathematics. This ensures that the integration of ethnomathematics is not merely supplemental but becomes an essential component of deep and relevant teaching strategies.

D. Conclusion

Ethnomathematical analysis of Fort Rotterdam indicates that numbers and measurements are used not only for the technical aspects of architecture but also as cultural symbols and historical markers. Activities such as counting, measuring, and designing reflect the philosophy of the Gowa Kingdom, defense requirements, and environmental adaptation.

These findings have significant implications for mathematics education, as integrating local cultural values and historical context can enhance conceptual understanding, problem-solving skills, learning motivation, and students' cultural identity. Thus, cultural heritage sites like Fort Rotterdam can serve as meaningful and contextualized sources for mathematics learning, linking formal concepts with real-world experiences and local symbolism.

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