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Application of the Concept of Geometric Transformation to the Patterns and Proportions of Heritage Architecture of the Cirebon Kejaksan Station

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ABSTRACT

The architecture of cultural heritage buildings not only represents historical and aesthetic values but also exhibits a regularity in form that can be studied through mathematical approaches. This research aims to examine the application of the concept of geometric transformation in the architectural patterns and proportions of the cultural heritage of the Cirebon Kejaksan Office Station and to uncover its relationship with local cultural values through an ethnomathematical perspective. The research uses a qualitative descriptive approach, with visual observation and photographic documentation of the building's front appearance components, including doors, windows, vents, arches, and ornaments. The analysis is focused on identifying geometric transformations in the form of reflection, shift, and magnification based on patterns of repetition, symmetry, and scale variation of architectural components. The results of the research show that the front view of the Kejaksan's Station reflects strong bilateral symmetry, shifts through the consistent repetition of door and window modules, and enlarges through variations in component dimensions that maintain the harmony of shape. In addition, the geometric patterns observed are consistent with the principles of repetition and balance in Cirebon culture, thereby reflecting the acculturation of colonial architecture with local values. These findings confirm that the Kejaksan Station has the potential to serve as a source of contextual learning in transformation geometry.

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1. INTRODUCTION

Heritage architecture is an important part of a city's cultural and historical identity, as it not only records social travel and technological developments, but also reflects the designer's perspective on space, proportion, and aesthetics. These cultural heritage buildings

generally exhibit regularity in their physical form, visual harmony, and an understanding of geometric shapes, evident in the repetition of design components, building structural units, window and door arrangements, and the arrangement of the front of the building. In the study of building science, geometry is an effective tool for systematically identifying the relationships among these shapes [1]. Various studies show that geometric aspects and dimensional comparisons have a crucial role in shaping the visual characteristics of architecture, both in traditional structures, colonial relics, and the contemporary era [2]. Therefore, the study of the geometric arrangement of historical buildings can deepen appreciation of the architectural and aesthetic qualities they embody.

Cultural heritage buildings are not only valuable from an architectural perspective but also have the potential to serve as context-based learning media across various fields of science, including mathematics [3]. The existence of a physical structure containing geometric elements, such as patterns, shapes, and proportional ratios, facilitates a more concrete and functional understanding of mathematical concepts. This approach supports the principle of learning that links abstract theory to real-life situations. Therefore, the study of geometric aspects of historical buildings not only benefits the development of architectural and historical science but also opens the possibility of using cultural heritage assets as a meaningful, real, and locally rooted educational resource.

However, although research on historical buildings in Indonesia is growing rapidly, the majority of studies are still focused on the historical dimension, the classification of forms, efforts to preserve the structure, the documentation of images, or the symbolic meanings they convey. Mathematical methods, especially the application of geometric shape change, have not been widely used as an analytical tool to study patterns and size comparisons of cultural heritage objects [4]. Several studies over the past five years have shown that geometric transformations can be applied to understand design patterns in decorations, front views, and certain spatial arrangements, such as museum buildings, colonial-era buildings, and city monuments [5]. Similar research also reveals that concepts of change, such as shift, reflection, and enlargement, can help identify the regularity of form and the principles of beauty that underlie architectural design [6]. However, research that thoroughly analyzes cultural heritage buildings through the lens of geometric changes in the structure of their shapes as a whole, not only in ornaments, remains very limited.

On an international scale, several recent studies have confirmed that geometric analysis can be used to evaluate architectural composition in a measured manner, including through the calculation of ratios, symmetry, and pattern regularity [7]. Research in classical and neoclassical architecture, for example, shows that mathematical comparisons, module-based patterns, and façade symmetry are important elements of architectural aesthetic appeal and can be identified structurally using geometric approaches [8]. This reinforces the urgency of an interdisciplinary approach between mathematics and building science, especially in cultural heritage buildings that are rich in orderly design structures and full of meaning.

In Indonesia, this kind of research opportunity is well-suited to colonial-era buildings built to modern design standards of the time, such as the Cirebon Kejaksan's Office. As a cultural heritage building with high historical and architectural value, Kejaksan's Station

displays structural patterns, the rhythm of its support columns, the arrangement of its openings, and its façade, which visually suggests the potential for geometric order. However, until now, no research has specifically examined the building using the concept of geometric change as an analytical method. In fact, this kind of analysis can provide a more comprehensive insight into the formal structure of buildings while supporting conservation efforts based on accurate data.

Building on this background, this research aims to close a gap in existing studies by systematically applying the concept of geometric change to analyze the patterns and proportions of cultural heritage architecture at the Cirebon Kejaksan Station. This approach not only describes the shape of the building visually or historically, but also examines its geometric structure in detail through the identification of transformations such as shift, reflection, rotation, and enlargement in architectural elements and design modules. Through this analysis, the research is expected to produce a measurable assessment framework that will make a significant contribution to the field of cultural heritage architectural studies and serve as a solid scientific foundation for the conservation, restoration, and documentation of historical buildings.

2. METHODS

This research employs a qualitative descriptive method to observe, depict, and assess the implementation of geometric changes in the architectural components of the Cirebon Kejaksan Station, based on visual information obtained at the research site. This method was chosen because qualitative research allows researchers to interpret objects in their natural context, resulting in a more comprehensive and deeper description [9].

In the qualitative method, the researcher is the primary tool for observation and information collection. Therefore, the researcher's sharpness of view of the object greatly determines the quality of the analysis [10]. The researcher examined the building's structure through visual observation of its front, including the layout of doors, windows, columned hallways, roof shapes, and decorative elements attached to the building.

Information collection includes both primary and secondary information. Primary information was obtained through direct observation and photography of the building's architectural components. This documentation method is also used in architectural geometry research on other cultural heritage buildings in Indonesia [11]. Secondary information was obtained through a literature review of journals, books, and scientific writings on ethnomathematics and historical architecture in Indonesia, to strengthen the interpretation of the cultural context of the discovery of geometric shapes in this building [12].

Information assessment is carried out through several stages: identification of geometric shapes and their transformations, followed by their association with aesthetic and cultural values. The initial stage is the study of geometric transformations to identify shifts, reflections, rotations, and enlargements visible on the front of the building, as previously implemented in the study of Islamic architecture in Indonesia [13]. The next stage is the study of ethnomathematics to interpret the relationship between geometric patterns and Cirebon cultural values, in line with research methods on other cultural heritage buildings in Indonesia, which show the correlation between architectural forms and local culture [14].

To maintain the validity of the information, this research applies source triangulation, comparing the results of visual observations, documentation photos, and literature reviews to minimize interpretation bias. The triangulation technique provides a more robust and valid understanding of the research object by drawing on multiple sources of information that complement one another [15].

With this method, this research is expected to produce accurate findings on the implementation of geometric transformation at the Cirebon Kejaksan's Office Station and to contribute to the development of mathematical studies integrated with Indonesian architecture and local culture.

3. RESULTS AND DISCUSSION

3.1 Results

History

Figure 1. Cirebon Kejaksan's Station in the Dutch Period
Source: Wikimedia Commons

Cirebon Kejaksan Station is one of the railway stations of historical significance in Indonesia and plays an important role in the development of transportation and the economy of the northern coastal area of Java Island [16]. The development of the railway system in Cirebon during the Dutch colonial era was closely linked to the rapid expansion of the plantation industry, especially the sugar industry, from the end of the 19th century onward. The need for an effective transportation system to move production to ports and distribution points encouraged colonial rulers to build railways in the region.

The year 1911 marked the start of construction of the Cikampek-Cirebon line by the Staatsspoorwegen (SS), a railway company owned by the Dutch East Indies government. This line was inaugurated and began operating on June 3, 1912, marking the start of the Kejaksan Station as a vital point in Java's railway transportation system. This line has

strategic value because it connects Batavia with major cities in Central Java and East Java via the northern route.

The structure of the Kejaksan Station building, which still stands today, was designed by Dutch architect Pieter Adriaan Jacobus Moojen. The station's design blends Art Nouveau and Art Deco, both popular in the early 20th century. This characteristic is seen in the symmetrical front-view arrangement, the use of arches in doors and windows, and the emphasis on clear, balanced geometric shapes. The main front view of the building shows a more prominent central part with two towers on the left and right sides, which, in colonial times, served as markers for the service area; each is inscribed "KAARTJES" for the ticket purchase area and "LUGGAGE" for luggage service.

From a functional perspective, Kejaksan Station not only serves passenger transportation but also plays an important role in distributing plantation products and trade commodities, especially sugar, which became a pillar of Cirebon's economy during the colonial period [17]. The presence of this station strengthens Cirebon's position as a port city and an important trade center on the northern coast of Java.

After Indonesia's independence, the Kejaksan Station continued to operate and develop in line with evolving transportation needs. This station is now managed by PT Kereta Api Indonesia (Persero), Daerah Operasi 3 Cirebon, and serves various classes of train travel. Several renovation and revitalization activities have been carried out, including repainting in 1984 and a massive revitalization in 2011, which improved platform facilities and passenger comfort without removing the original architectural character.

Recognizing its historical, architectural, and cultural value, Kejaksan's Station was designated a cultural heritage building in 2010. This status confirms that Kejaksan Station not only serves as a means of transportation but also as a cultural heritage asset that records the historical journey, technological advancements, and the aesthetics of colonial architecture in Cirebon City. To this day, this building remains one of the important icons that represent Cirebon's historical identity and urban development from the colonial era to modern times.

The above historical exposure shows that the Cirebon Kejaksan Station not only retains historical and functional value, but is also designed with aesthetic aspects and a strong regularity of form in mind. To understand the visual order and formal structure of buildings more objectively, analysis using a mathematical approach is needed, especially through the study of geometric transformations in their architectural components.

Geometry Transformation

Reflection

At the front of the Cirebon Kejaksan Station, the concept of geometric transformation, specifically reflection, is prominently and systematically implemented. This building has a vertical, symmetrical line exactly in the center of the front view, so if the front view is divided by an imaginary line, the left and right sides of the building are mirror images of each other. This reflection illustrates the principle of bilateral symmetry, in which each component on one side has a matching counterpart on the opposite side in terms of shape, dimensions, and location.

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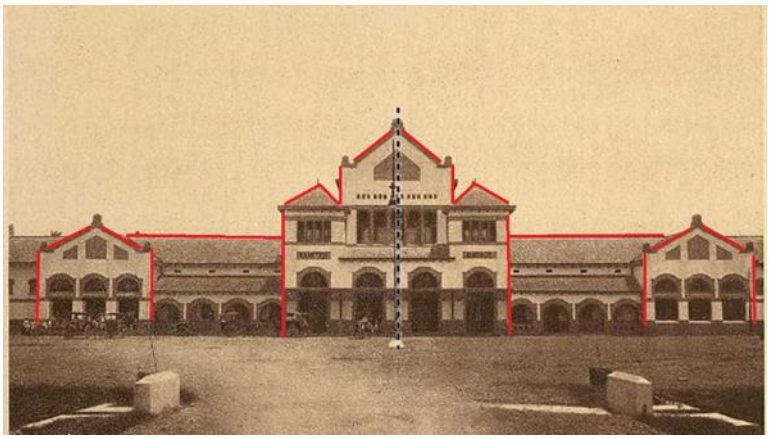

Figure 2. The application of geometric transformation in the form of reflection (bilateral symmetry) on the front view of the Cirebon Kejaksan Station

This balance is evident in the roof arrangement, which has uniform angles of inclination, height, and shape on both sides of the building. In addition, the row of arches at the bottom of the front view is arranged in a balanced manner, with the number, spacing between components, and consistent size from left to right. Opening components, such as doors, windows, and vents, as well as decorative ornaments, exhibit a design and placement pattern that reflects symmetrical lines. This implementation of mirroring creates a strong visual order and gives a stable, formal, and monumental impression, a typical characteristic of 20th-century colonialism.

On the other hand, the regularity arising from the composition of the roof with uniform degrees of slope and elevation has the potential to diminish the distinctiveness and innovation in building design. If all parts of the building have identical shapes, this condition can result in a flat impression and make the building less visually appealing. Furthermore, the row of curved elements on the façade, arranged symmetrically with fixed dimensions and intervals, can actually eliminate the lively character or visual appeal and even give a rigid, less expressive impression.

Figure 3. The application of geometric reflection on the façade of the Cirebon Kejaksan Station can be seen in the left-center-right division of the structure and the symmetry of the elements of doors, windows, and arches.

Reflections are not only evident at the overall scale of the front view but also in the division of the building structure into three main segments: left, center, and right. The middle part serves as the central point of symmetry, visually more dominant in both height and shape, while the left and right parts are mirror images of each other. This shows that the principle of reflection is applied at multiple scales, from the building's large scale to its more detailed architectural components.

The application of the principle of reflection to a building's appearance not only creates a visual effect but also shapes the psychological dimension and how individuals interpret architectural spaces. Studies have shown that the presence of strong symmetry on a building's façade can enhance the impression of order, ease of reading the structure, and the sensation of visual harmony for the observer. The symmetry of the mirrors facilitates the recognition of spatial orientation and levels of architectural elements, making the façade more communicative and visually accessible. In cultural heritage buildings, this reflection plays a crucial role in preserving visual characteristics while emphasizing their beauty and historical significance. This perspective is supported by Aydin and Mirzaei's research, which underlines that symmetry has a substantial impact on the aesthetic appreciation of building façades [18]. Furthermore, Katena's study demonstrates that the symmetrical regularity of classical and colonial buildings is closely related to comprehensive rules of mathematical composition that contribute to the continued visual appeal of historic structures [19].

Thus, the reflection at the Cirebon Kejaksan's Station has an important role in forming a proportionate and harmonious architectural composition. This implementation of bilateral symmetry not only serves as an aesthetic strategy but also reflects a rational, mathematical approach to the design of colonial buildings, where visual balance and the regularity of form are the main foundations for the creation of representative and characterful architecture.

The implementation of the reflection on the front view of Kejaksan's Station shows that the regularity of the building's shape is achieved not solely through bilateral symmetry, but also through the structured repetition and variation of the dimensions of its elements. In addition to reflection, this building also demonstrates the application of geometric transformations, such as dilation and translation, which consistently create visual rhythms and proportions in architectural elements.

Dilation & Translation

The implementation of the concept of geometric transformation through translation is clearly evident in the arrangement of door and window elements in the main front view of Cirebon Kejaksan Station. In geometry, translation or shift is a transformation that moves an object as far as a certain vector without changing its shape, dimensions, or direction [20]. In this building, translation is consistently applied, forming an arrangement of architectural elements that is neat, orderly, and has a clear visual rhythm.

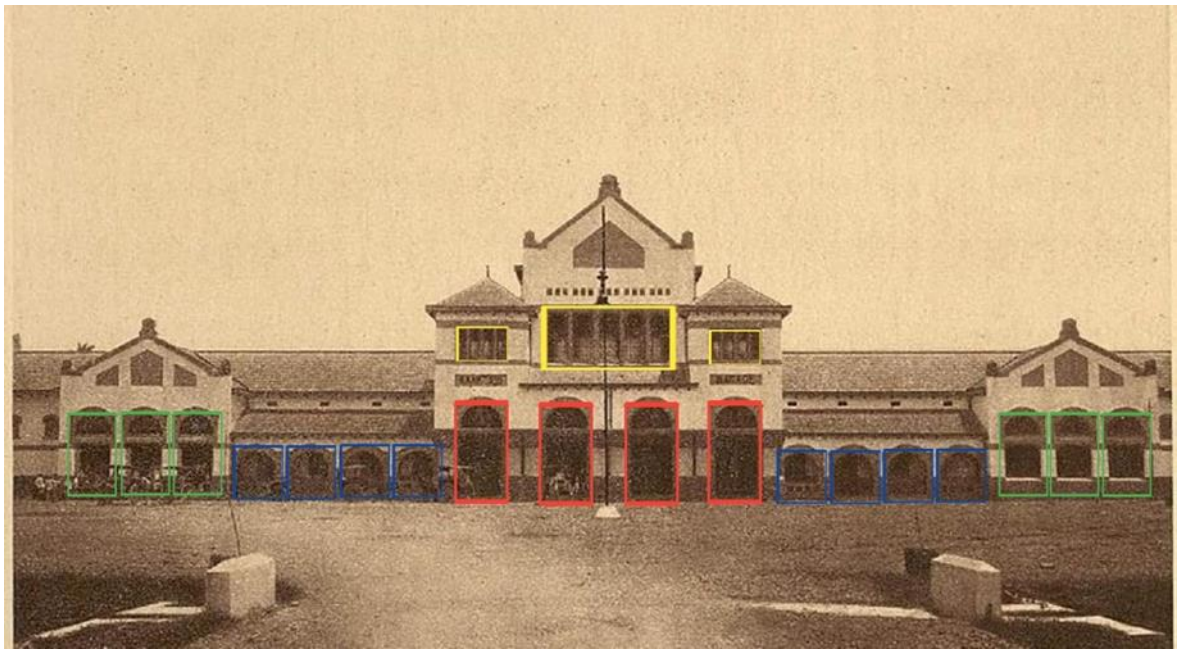

Figure 4. The application of geometric transformation in the form of translation and dilation on the front view of the Cirebon Kejaksan's Station, which forms the regularity of patterns and proportions of architectural elements

The row of doors in the center of the front view repeats an identical rectangular shape and is arranged horizontally, with relatively uniform spacing between its components. This pattern shows that each door results from the same shape shifting in a given direction, reflecting the uniform application of translation. Mathematically, these conditions suggest that the doors can be seen as the result of mapping the shift from one basic shape to another with a fixed displacement vector.

A similar shift pattern is also seen in the arrangement of windows on the left and right sides of the front of the building. The windows have uniform shapes and dimensions and are placed at consistent intervals, forming a regular linear row. The implementation of shifts in the windows not only reinforces the impression of visual regularity but also demonstrates a modular principle in building design, where a single basic module is used repeatedly to construct the entire façade composition.

The application of translation principles in architectural components not only creates visual harmony but also enhances the user's ability to understand the space's organization and find orientation within the building. The repetition of elements such as doors and windows through systematic shifts helps visitors understand spatial patterns and area designation naturally, especially in wide-dimensional public facilities such as train terminals. From a design perspective, the repetition of identical elements is an economical approach because a single form can be duplicated without requiring structural adjustments, reflecting the modular concept and development efficiency that characterized colonial architecture in the early twentieth century. The results of this observation are consistent with Richard's view that the application of translation in design not only maintains the suitability of proportions but also contributes to the firmness of the visual arrangement and the consistency of the spatial composition in public service buildings [21]. At the Kejaksan

Station, translation extends beyond mere geometry and becomes the foundation for the building's façade's systematic, distinctive, and functional character.

In addition to shifts, the concept of dilation, or enlargement, can be identified in some architectural elements of Kejaksan Station. Dilation is a geometric transformation that changes the dimensions of an object proportionally without changing its basic shape [22]. In the front view of this building, an enlargement shows variation in the dimensions of the opening, especially the difference in scale between the main door, the large window, and the smaller window. Despite the different dimensions, the components still maintain a similar shape, indicating a proportional scale relationship.

The magnification is evident in the small windows arranged within a single front-view plane, where the rectangular base is reduced proportionally to the main window. Mathematically, this condition states that a small window is obtained by enlarging a larger window by a given scale factor. The use of this type of dilation serves to adjust lighting and air circulation requirements while maintaining the building's visual harmony [23].

Translation and dilation in the front view of Cirebon Kejaksan Station play an important role in shaping the regularity of patterns, visual rhythms, and the proportions of buildings. Shift creates consistent repetition of components, while magnification regulates proportional variation in component dimensions. These findings show that the principles of geometric transformation not only function as abstract mathematical concepts but are also applied in practice in the design of cultural heritage architecture, suggesting they have potential as a source of contextual learning in mathematics education, especially in geometric transformation materials.

Ethnomathematics

Ethnomathematics at the Cirebon Kejaksan's Office Station can be interpreted as the study of mathematical practices, ideas, and representations integrated into local culture through architectural forms of cultural heritage buildings. Although the Kejaksan Station is a product of Dutch colonial architecture, its geometric structure and visual elements are not entirely divorced from Cirebon's local cultural context. This shows that the building results from an intercultural interaction that combines the principles of formal European mathematics with the aesthetics and values of local culture.

The geometric patterns in the elements of the roster, ventilation, and building ornaments show similarities with traditional Cirebon motifs, such as the principles of repetition and symmetry, which are also found in Mega Mendung batik. The motif mathematically represents the concept of geometric transformation through shifts and mirroring, in which a single basic shape is repeated at a consistent distance and direction. From an ethnomathematical perspective, the repetition of this pattern not only serves as a decorative element but also reflects how local communities perceive order, balance, and harmony in visual space [24].

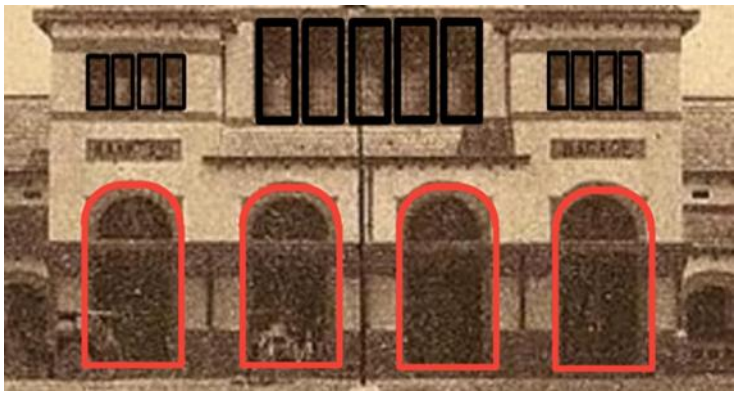

Figure 5. Ethnomathematics in the architecture of the Cirebon Kejaksan's Office Station as a result of the acculturation of colonial geometric principles and local cultural values

In addition, the rhythm of the window's repetition, the distance between columns, and the consistent building model demonstrate the everyday application of the concept of numbers and proportions in harmony with the principle of regularity in Cirebon culture. This value of regularity aligns with a local philosophy that emphasizes a balance among function, aesthetics, and the environment. Thus, the building's structure is not only designed on technical grounds, but also reflects a cultural perspective on neat, measurable spatial planning.

The curved shape of doors, windows, and other front-facing elements also has ethnomathematical significance. The curve can be analyzed using the concepts of curve geometry and magnification transformation, in which the basic shape is proportionally enlarged or reduced. Culturally, arches are found in traditional Cirebon architecture, such as palace buildings and old mosques, and symbolize softness, continuity, and visual balance. This shows that the choice of curved shapes at the Kejaksan Station is not solely structural but also resonates with local aesthetics.

The combination of the principles of proportion in colonial architecture and geometric patterns with local nuances shows that mathematics in this building serves as a medium of cultural acculturation [25]. Ethnomathematics in the context of the Kejaksan Station does not exist as abstract, formal mathematics, but as a cultural practice manifested in the repetition of shapes, symmetry, proportions, and geometric transformations in architectural components. Thus, the Cirebon Kejaksan's Office Station can be understood as a visual representation of how the concept of mathematics lives and develops in cultural space through its architectural heritage.

3.2. Discussion

The results of the study show that implementing the concept of geometric transformation in the front view of the Cirebon Kejaksan's Station not only displays symmetrical, orderly visual aspects but also reveals a design structure consistently shaped by mathematical principles. The reflections on the main front view, for example, reinforce the character of colonial architecture, which prioritized the balance of composition and the harmony of form. This symmetry demonstrates that Moojen architects strictly applied the principles of proportion and symmetrical lines to create monumental, harmonious structures.

The findings are in line with previous research's view that placed symmetry as a key element in colonial and neoclassical architectural aesthetics.

The findings regarding shifts in the rows of doors, windows, and front-view components indicate that module repetition is an important design strategy in shaping visual rhythms. The arrangement of the doors in the center and the windows on the left and right shows a uniform pattern of repetition, both in terms of dimensions and distances between the components. Structurally, this shift enhances the design's readability while emphasizing the building's function as a public space that requires clear orientation. This pattern of repetition is also evident in other studies, which find that shifting is one of the most frequent transformations in colonial buildings because it effectively creates visual regularity and compositional stability.

Ethnomathematical analysis provides additional dimensions that enrich the meaning of building geometry. The presence of ornaments resembling Mega Mendung batik motifs, repetitive patterns on the roster, and curves reminiscent of traditional Cirebon architecture indicates that the mathematical expression in the building is not purely technical but is also intertwined with local cultural values and symbols. The integration of cultural values and colonial design shows that Kejaksan's Station is not only a colonial artifact, but also a container for aesthetic acculturation that displays geometry as part of Cirebon's cultural identity. These findings corroborate previous ethnomathematical research, which confirms that mathematical forms in architecture are often rooted in traditional values and local cultural practices.

The results of this study show that the geometric transformation approach is not only relevant for reading the formal structure of buildings but can also be used to interpret the relationships among mathematics, architecture, and local culture. This analysis confirms that Kejaksan's Station is a real example of how mathematical concepts operate in cultural heritage architecture, combining colonial modern design techniques with Cirebon local aesthetic values.

4. CONCLUSION

This study has shown that implementing the concept of geometric transformation makes a significant contribution to understanding the formal structure and aesthetic value of the architecture of the Cirebon Kejaksan's Office. Based on the results and discussion, it can be concluded that this building exhibits a transformation pattern of reflection, shift, and enlargement, systematically arranged in its front view. Reflection is evident through a vertical, symmetrical line that divides the front view into two corresponding parts, while the shift is seen in the consistent repetition of doors and windows, both in their dimensions and in the distances between their components. These components show that mathematical principles became an important basis in the creation of neat, proportional, and monumental colonial architectural forms.

In addition, ethnomathematical analysis shows that the geometric patterns at Kejaksan Station are not only technical but also related to the local culture of Cirebon. The presence of ornaments that resemble traditional motifs, the rhythmic arrangement of the space that reflects the value of order, and the curved shape in line with the aesthetics of

Cirebon's coastal architecture indicate an acculturation between colonial design and local cultural values. This makes Kejaksan Station a cultural heritage building that is not only historically important but also mathematically and culturally rich.

This research also fills a gap in previous studies, which remain limited in their application of geometric transformations to analyze the structures of cultural heritage buildings comprehensively. In the future, research can be conducted on other cultural heritage objects in the Cirebon or Indonesia regions to strengthen the foundation of mathematical studies in traditional and colonial architecture. In addition, quantitative analysis using digital tools, such as geometry modeling software, can be an advanced step toward producing more precise documentation of building structures and supporting data-driven preservation efforts.

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