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Geometric Transformations in the Lawang Sanga Gate of the Kasepuhan Palace, Cirebon: An Ethnomathematical Measurement Study

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ABSTRACT

Studies of the Lawang Sanga Gate at the Kasepuhan Palace, Cirebon, have focused on its history and symbolism, whereas its geometric form has not been formally measured. This study examines how far translation, reflection, and dilation can be identified in the architectural elements of the gate. A descriptive qualitative design with an ethnomathematical perspective was used, combining field observation, tape measurements (precision ±0.5 cm) of doors, pillars, mouldings, and ornaments, photographic documentation, and an interview with a key informant. Patterns were coded as transformations, and their regularity was quantified with successive differences and ratios, left–right differences, and the coefficient of variation (CV). Reflection is the most consistent transformation: the three bays of the front façade (285, 180, and 285 cm) and the crown ornament are mirror-symmetric about the central axis, although corresponding pillars on the inner front wall differ in width by 18–23 cm. Translation is clearest in the spacing of the curved lines of the central arch (15.6, 15.8, and 16.6 cm; CV = 3.3%). In the central arch, blind arch, and rear door, successive mouldings change in width by ratios of 0.94–1.08, which approximates, but does not strictly satisfy, dilation, and the width-to-height ratio of the pillars is not constant (1:1.5 to 1:3.1). These findings indicate that the builders applied mirror symmetry and repetition deliberately at the level of layout and ornament, whereas sizes were scaled only approximately. The study provides baseline measurements for conservation and for ethnomathematics-based learning; higher-precision three-dimensional documentation is needed to confirm the proportions.

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1. INTRODUCTION

Traditional architecture in the Indonesian archipelago carries aesthetic and symbolic value and often also embodies regular geometric and spatial structures. A notable example is the *Lawang Sanga* of the Kasepuhan Palace, Cirebon, a gate with nine doors that is also known in historical sources as *Nawa Gapura Marga Raja*. Drawing on studies of old manuscripts and on interviews with members of the palace family and cultural experts, Abdillah et al. concluded that the gate was built by Prince Wangsakerta around 1677 AD, during the reign of Sultan Sepuh I Syamsudin Martawidjaja [1]. Its nine gates, gathered in a single building, give rise to the name *Lawang Sanga* ("nine doors") and have been linked to the nine gates of the Sunan Gunung Jati burial complex [1]. In Cirebon symbolism, the number nine is also associated with the Wali Songo [2].

The gate has been studied as material heritage that expresses symbolic values, religious-cultural acculturation, and the social practices of the Cirebon court [1], [3], [4]. These studies, based on document analysis, observation, and interviews, emphasise the symbolic meaning, cultural significance, and religious-cultural value of nine doors in a single building. Functionally, *Lawang Sanga* was first built as the entrance for *Gotrasawala*, a gathering of rulers of the archipelago hosted by the Cirebon Sultanate, and later served as the entrance to the harbourmaster area on the riverbank and as an escape door for members of the palace family [5].

In contrast, the formal geometric structure of *Lawang Sanga*, namely its symmetry, proportion, and geometric transformations, has received little attention. Abdillah et al. analysed the form of the gate through art criticism and visual narration rather than measurement [3]. Paradita classified the gates of the Kasepuhan Palace into three basic forms (*candi bentar*, *paduraksa*, and *semar tinandu*) and placed *Lawang Sanga* in the *paduraksa* group, but described symmetry and proportion only qualitatively [6]. Architectural studies have traced the spatial development of the Kasepuhan Palace and the shape transformation of the Cirebon *sitihinggil* relative to Majapahit architecture [7], [8]. In contrast, ethnomathematical studies in Cirebon have identified plane and solid figures, symmetry, and reflection in the Kasepuhan and Kacirebonan palaces [2], [9]–[11] and used them in mathematics teaching [12]. As far as the authors' search indicates, none of these studies measures *Lawang Sanga* or tests geometric transformations against dimensional data.

Elsewhere in Indonesia, ethnomathematical studies of heritage buildings and traditional houses have shown that transformation geometry (reflection, translation, rotation, and dilation) offers a productive lens for reading architectural form [13]–[20]. A recent review of 64 ethnomathematical studies of historical buildings found that ethnographic designs dominate this body of work [21]. Applying a measurement-based transformation perspective to *Lawang Sanga* can therefore extend the understanding of Cirebon's architectural heritage and provide a quantitative basis for its documentation and conservation.

This study therefore analyses *Lawang Sanga* from the perspective of transformation geometry. It identifies the axes of symmetry of the gate, measures the dimensions of its doors, pillars, mouldings, and ornaments, and examines whether the measured patterns are

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consistent with translation, reflection, and dilation. The contributions of the study are (i) a measured formal analysis that complements the literature on Cirebon traditional architecture; (ii) a methodological approach to heritage studies that combines geometry, visual documentation, and historical sources; and (iii) baseline dimensional data that can inform conservation that respects the geometric integrity of the gate.

2. METHOD

This study employs a descriptive qualitative approach with an ethnomathematical perspective to identify the application of geometric transformation concepts, namely translation, reflection, and dilation, in the traditional architecture of the Lawang Sanga Gate at the Kasepuhan Palace, Cirebon. This approach was selected because the research emphasizes the interpretation of form, pattern regularity, and cultural meaning rather than formal mathematical proof.

Field observations were conducted directly at the Lawang Sanga site by defining several main observation points: (1) the main gate structure, (2) the left and right pillars, (3) the upper curved ornaments, and (4) repetitive carving patterns on the side walls. The measuring instrument used in this study was a cloth measuring tape (tailor's tape) with a precision of ±0.5 cm. This instrument was selected due to its flexibility in following non-flat surfaces and curved ornamental elements. To reduce potential measurement error caused by material elasticity, each measurement was repeated two to three times at the same location and averaged. Measurement consistency across repetitions was used as an indicator of data reliability. All dimensions are reported in centimetres; in the figures, *l* and *t* denote width (*lebar*) and height or thickness (*tinggi*). Values are reported as recorded (means of repeated readings), except layer thicknesses below 2 cm, which are rounded to the nearest 0.5 cm to match the instrument precision; differences smaller than about 1 cm, i.e. twice the instrument precision, are treated as lying within measurement error.

The observational data were analysed using a geometric transformation coding scheme. Patterns were classified as translational when repeated forms appeared at relatively uniform intervals, reflective when corresponding elements matched across a specific axis, and dilational when successive forms were enlarged or reduced by a stable ratio. To make the coding verifiable, the regularity of each measured sequence was quantified with successive differences (translation), successive ratios (dilation), left–right differences between corresponding elements (reflection), and the coefficient of variation, $CV = (s/\bar{x}) \times 100\%$, where s is the sample standard deviation and $\bar{x}$ is the mean. A sequence was regarded as regular when its spacing varied by no more than about 1 cm, or its CV was below 5%. These indices, summarised in Table 2, served as the basis for the visual and descriptive interpretation of the architectural elements.

In addition to observation, a semi-structured interview was conducted in 2025 with one key informant, selected on two criteria: (1) familiarity with the history and cultural meaning of the Lawang Sanga Gate, and (2) residence in the Kasepuhan Palace environment. The interview focused on the origin of the building, the symbolic function of the gate, and the rationale behind specific ornamental patterns. The interview data were analysed thematically and used to triangulate the geometric and visual findings. The interview data

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are not reported as a separate section; they were integrated into the descriptive interpretation of the history, symbolic function, and ornamental patterns of the gate presented in Sections 1 and 3, and were used to triangulate the geometric and visual findings.

Documentation techniques included the collection of photographs, measurement records, and relevant literature on Cirebon's history and traditional architecture. This documentation enabled repeated examination of visual details that might not be clearly observable during fieldwork. The research was conducted with permission from the Kasepuhan Palace authorities, and informed consent was obtained from the informant.

3. RESULTS AND DISCUSSION

3.1. Results

Measurements were taken on the main door, side doors, rear doors, and the curved elements at the top of the building with the cloth measuring tape described in Section 2. They covered door widths, pillar widths and heights, the spacing between ornaments, and the dimensions of the layered mouldings.

Table 1 shows the building elements analysed, and Table 2 summarises the measured dimensions together with the regularity indices derived from them.

Table 1. Building elements of Lawang Sanga analysed in this study

No.	Element	Photographs
1	Front façade with three arched bays (Figs. 2–4)	
2	Rear side doors, facing pair (Fig. 5)	 
3	Main door, front and rear faces (Figs. 1 and 7)	 
4	Blind arches on the side walls (Fig. 8)	 

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Table 2. Measured dimensions and regularity indices of the main elements

Element (figure)	Measured values (cm)	Derived index
Pillar, side arched door (Fig. 3)	w = 44.5; h = 136	w:h = 1:3.06
Pillar, central arched door (Fig. 4)	w = 89; h = 136	w:h = 1:1.53
Pillar, rear side door (Fig. 5)	w = 54; h = 139	w:h = 1:2.57
Front façade bay spans between pillars, L–C–R (Fig. 2)	285; 180; 285	L–R difference = 0; spacing CV = 24.2%
Inner front wall pillars, L1, L2 | R2, R1 (Fig. 7)	56; 61.5 | 84.5; 74	L–R difference = 18.0 (outer), 23.0 (inner)
Curved-line spacing, central arch (Fig. 4)	15.6; 15.8; 16.6	mean = 16.0; CV = 3.3%
Moulding widths, central arch (Fig. 4)	94.5; 97.5; 105	ratios 1.03, 1.08
Moulding widths, side arch (Fig. 3)	47; 52.5; 44.2	ratios 1.12, 0.84 (non-monotonic)
Moulding widths, rear door, top to base (Fig. 5)	65; 61.5; 60; 56.3; 54	ratios 0.95, 0.98, 0.94, 0.96
Moulding widths, blind arch (Fig. 8)	59; 63; 65; 69.4	ratios 1.07, 1.03, 1.07
Layer thickness, upper curve (Fig. 9)	6; 5.5; 7	non-monotonic

w = width; h = height; L = left; C = centre; R = right; ratios are successive values divided by the preceding value.

3.2. Discussion

Main Door of the Room

The opening of the main door inside the building is 211 cm wide, with the same value measured on its front and rear faces (Figure 1). This front–rear consistency indicates a uniform opening through the thickness of the wall. The bilateral (left–right) symmetry of the door is supported visually by the paired lamps and pilasters on either side, although it was not measured directly. Functionally, the wide opening accommodates movement, while aesthetically it reinforces the prominence of the door as the main access point.

From an ethnomathematical perspective, this element illustrates how functional needs and spatial aesthetics converge through orderly proportions. Although the craftsmen may not have employed formal mathematical notation, the consistency of dimensions reflects an implicit understanding of balance and symmetry that can be formally described using geometric principles.



Figure 1. Main door inside the Lawang Sanga building (opening width 211 cm)

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3.2.1 Geometry Transformation Analysis

3.2.1.1 Translation



Figure 2. Front façade of Lawang Sanga with the measured widths of the three bays

The clear spans between the pillars of the three bays of the front façade measure 285 cm on the left, 180 cm in the centre, and 285 cm on the right (Figure 2). Because the spacing is not uniform (CV = 24.2%), this arrangement does not constitute a translation. Instead, the equality of the two outer bays on either side of a narrower central bay is a reflection about the central axis, which is discussed in Section 3.2.1.2, and the narrower central bay directs attention toward that axis.

In ethnomathematical terms, translation corresponds to the craft practice of reproducing a form at regular intervals to achieve rhythm. In *Lawang Sanga*, this practice is most clearly measurable at the scale of the ornament rather than of the bays, as shown by the curved lines of the central arch below. Where such repetitions display measurable consistency, they constitute formalisable mathematical structures.

Side doors and rear doors



Figure 3. Side arched door: pillar and moulding dimensions

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The side arched door (Figure 3) has a main pillar 44.5 cm wide and 136 cm high. The upper profile of the pillar consists of three layers 47, 52.5, and 44.2 cm wide, each about 1.5 cm thick. The layers repeat the same profile vertically, which is consistent with a vertical translation of the moulding form. Their widths, however, do not change monotonically (Table 2), so the repetition is one of form rather than of exact dimension.



Figure 4. Central arched door: pillar, moulding, and curved-line dimensions

The central arched door (Figure 4) has lower pillars 89 cm wide and 136 cm high, exactly twice the width of the side-door pillar measured on the same face and at the same height. Above the pillar, three moulding layers measure 94.5, 97.5, and 105 cm in width and 1.0, 1.5, and 1.5 cm in thickness. The horizontal distances between the curved lines on the right side are 15.6, 15.8, and 16.6 cm (mean 16.0 cm, CV = 3.3%), and the horizontal curved line is 29.5 cm long. The near-constant spacing of the curved lines, which varies by only about twice the measurement precision, is the clearest instance of translation in the gate: each curved line can be read as the image of the previous one under a horizontal translation of approximately 16 cm.



Figure 5. Rear side door: moulding widths and thicknesses

The rear side door (Figure 5) has a base opening of about 150 cm. On the left pillar, the moulding widths from the top downward are 65, 61.5, 60, and 56.3 cm, with thicknesses of 12, 4.3, 8.5, and 3.3 cm, and the pillar shaft below is 54 cm wide and 139 cm high. The widths decrease steadily downward, with successive ratios between 0.94 and 0.98, whereas the thicknesses alternate between thick and thin layers. The graded widths suggest a

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combination of vertical translation and approximate scaling. The door directly opposite was observed to show a similar pattern of proportions.

Taken together, the side, central, and rear doors share a common construction logic: the moulding profile is repeated layer by layer, and widths are adjusted in small steps rather than duplicated exactly. This reflects ethnomathematical knowledge in which regularity emerges through practice and tradition rather than through formal calculation.

3.2.1.2 Reflection



Figure 6. Crown ornament above the main door with its vertical axis of symmetry

The crown ornament above the door (Figure 6) is symmetric about the vertical centreline. Its left and right halves mirror each other, from the small scroll at each end to the large protrusion in the middle, so that one half is the image of the other under a reflection in the centreline. Together with the roof structure, which slopes along the contour of the ornament, this correspondence reflects the care taken by the builders to maintain visual balance.



Figure 7. Inner front wall: widths of the pillars on either side of the main door

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The pillar widths measured on the inner front wall (Figure 7) are 56 and 61.5 cm to the left of the main door and 84.5 and 74 cm to its right. Corresponding pillars therefore differ by 18.0 cm (outer pair) and 23.0 cm (inner pair), far beyond the measurement precision. The wall thus shows reflective symmetry in the number and arrangement of its pillars, but not in their widths.

Reflective symmetry is therefore clearest in the upper ornamentation and in the bay arrangement of the front façade, where corresponding elements match in both form and measured size.

Within ethnomathematics, such symmetry is interpreted as culturally transmitted knowledge of order and balance. The mismatch in the inner wall pillars suggests that mirroring governed the overall layout, while individual dimensions were adapted to structural needs or were altered by later restoration; the present data cannot distinguish between these explanations.

3.2.1.3 Dilation

Dilation can be examined in the blind arches on the side walls and in the layered upper curves of the arched doors (Figures 8 and 9).



Figure 8. Blind arch on the side wall: arch, moulding, and pillar dimensions

The blind arch on the side wall (Figure 8) has an opening 76 cm wide with a rise of 53 cm, and the curved reliefs on both sides are about 5 cm thick. Below the springing of the arch, four moulding layers measure 59, 63, 65, and 69.4 cm on the left side, and the right side was observed to follow the same pattern. The pillars rise 138 cm from the base to the springing of the arch, and the opening between them at the base is 74.4 cm wide. Successive moulding widths increase by ratios of 1.07, 1.03, and 1.07.



Figure 9. Layered upper curve of the arched door

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The upper curved part of the arched door (Figure 9) is about 35 cm wide on the right side, with layer thicknesses of 6, 5.5, and 7 cm. Because the thicknesses do not increase monotonically, these layers represent the repetition of a curved profile rather than a successive enlargement. The door opposite was observed to have a similar structure.

Dilation therefore appears only approximately. The widths of successive mouldings grow by 3–8% per layer in the central arch and the blind arch and decrease by 2–6% per layer in the rear door, but the ratios are not constant, and the layer heights do not scale with the widths. A dilation requires a single scale factor applied to all dimensions about a centre. The relation between the central and side pillars (89 and 44.5 cm wide at an equal height of 136 cm) is likewise a one-directional stretch by a factor of 2 rather than a dilation, which would also scale the height. The moulding sequences are therefore best described as graded enlargement or reduction that approximates dilation.

In ethnomathematical interpretation, this graded scaling represents a transition from intuitive adjustment of size to spatial or structural needs toward a formalisable proportional system. The recurrence of small, graded size steps across several elements suggests that approximate scaling was part of a shared construction logic.

3.2.2 Meaning of Symmetry

The symmetry in the structure of *Lawang Sanga* is not only an attractive visual pattern; it may also carry philosophical, structural, and functional meanings. Symmetry appears in the front façade, the arrangement of the pillars, the shape of the door arches, and the composition of the spaces that face each other. Based on the measurements and field documentation, the left and right sides of the building mirror each other in layout and ornament, so that the structure follows the principle of reflection about a single vertical axis.

Ethnomathematical studies of Javanese heritage architecture show that geometric patterns often carry philosophical value in addition to their aesthetic function [16]. In *Lawang Sanga*, the form of the nine doors has been linked to religious teachings, cultural values, and leadership values [1], [3]. Read in this light, the symmetry of the paired doors may also express the values of balance and harmony, so that the building serves not only as a practical gate but also as a carrier of philosophical meaning.\

Wulandari et al. identified reflection in the curved entrance arch of the Kasepuhan Palace [2], and Sofhya and Az-Zahwa found reflection on most of the gates of the Kacirebonan Palace [10]. The present findings are consistent with these reports and extend them by showing, with measured data, where the mirroring holds (layout and ornament) and where it does not (individual pillar widths). The presence of reflection in the arrangement of curves, pillars, and wall planes indicates that the builders applied the principle of symmetry intuitively while maintaining the visual stability of the building.

From the perspective of transformation geometry, symmetry in *Lawang Sanga* is represented mainly by reflection. Elements on the left correspond closely to those on the right in ornamental form and in the bay arrangement of the façade, but not in every measured dimension (Table 2). Ethnomathematical studies of other heritage gates and Islamic buildings likewise identify reflection as a recurrent design principle [15], [17].

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In addition, symmetry may contribute to spatial readability and visual orientation. The side doors facing each other create an orderly line of sight, so that visitors can perceive the rhythm of the space from one gate to another. This symmetrical structure helps visitors understand the flow of space intuitively by emphasising order, direction, and balance between the parts of the building.

Thus, the meaning of symmetry in *Lawang Sanga* is related not only to the visual or technical aspects of construction but also to local mathematical thinking and philosophy. The regularity of form expressed through reflection links the mathematical order of the gate with its functional and cultural values.

4. CONCLUSION

This study set out to identify geometric transformations in the Lawang Sanga Gate of the Kasepuhan Palace through field measurement and ethnomathematical analysis. Reflection is the most consistent transformation: the bay arrangement of the front façade and the crown ornament are mirror-symmetric about the central axis. Translation is clearest in the evenly spaced curved lines of the central arch and in the repetition of moulding profiles. Dilation appears only approximately, as graded enlargement or reduction of successive mouldings without a constant scale factor, and the width-to-height ratio of the pillars is not constant across doors. Mirroring also does not extend to every individual dimension, as shown by the unequal pillar widths on the inner front wall. Taken together, these results indicate that the builders applied mirror symmetry and repetition deliberately at the level of layout and ornament, while adjusting individual sizes in practice rather than following a fixed proportional rule. The study thus complements historical and symbolic accounts of Lawang Sanga with measured evidence of its geometric order and provides baseline data for conservation and for ethnomathematics-based learning. Its conclusions are limited by tape measurements of moderate precision, by access to visible elements only, by reliance on a single key informant, and by possible alterations caused by ageing and restoration. Three-dimensional digital documentation, paired left–right measurements of all elements, and comparison with other gates of the Kasepuhan complex are recommended to test the proportional patterns more rigorously.

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