# Simple House Theory In Some Buginese Traditional Houses

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**Abstract.** Humans' natural mathematical abilities have propelled civilizations forward. Mathematics is an integral component of all cultural contexts, and the significance of all cultural contexts is influenced by the individual's interpretation within that culture. These interpretations have been demonstrated in cultural heritage, particularly traditional houses, which show evidence of intuitive mathematics ability. Tribes worldwide have built traditional houses in their distinct styles. The current study included data collection through documentation, observation, and interviews. Camera images, aerial camera images, and documentation techniques were used to observe several traditional buildings in Indonesia. We used projective geometry and simple house theory to analyze of the sample of traditional Houses. The result of the traditional house are (1) traditional house from NTB (west Nusa Tenggara) and Wajo ( Saoraja Latenri Bali) have building numbers and Projective coordinate $(\hat{4}_{1\_1}, \hat{4}_{1\_2}, \hat{4}_{1\_3})$, and chategorized as Simple house IV (2)Traditionla houses from Sidrap and Bone is categorized as simple house V with projective coordinate $(\hat{5}_{1\_1}, \hat{5}_{1\_2}, \hat{5}_{1\_3})$

**Keywords:** House Theory, Projective Geometry, Traditional Houses, Building Numbers, Projective Coordinates

## INTRODUCTION

The study of mathematics has benefited human civilization and crucial as tools for problem solving. The human aspect of reasoning has profited from mathematics, and people use it to solve issues. (Kelter, Carr and Scott 2003).

Since the beginning of history, humans have understood the applications of mathematics, particularly geometry. Mathematics is the oldest branch of knowledge in the world. Some prehistoric societies, like the wall murals in a vast limestone cavern in Southern France, demonstrate that people have a fundamental mathematical understanding of shape and space. On pottery and textile shards, several geometric motifs are still visible. (Holme 2010).

Numerous aspects, including economic, political, social, linguistic, religious, and ideological, are impacted by the mathematical concepts. (Kelter, Carr and Scott 2003, Holme 2010). For instance, it's simple to identify daily instances of people using mathematics subconsciously. They address their issues with the aid of rationality.

Even some people use their mathematical talent to create art or physical structures. We may therefore argue that mathematics is inherited and present in their lives.

Many cultures and societies have benefited from the development of mathematics. Modern mathematics has benefited from the contributions of different cultures and societies. It is because of this that mathematics is a cultural and social product. (Alangui 2010). The traditions and expectations of the society's members as part of constitutional and cultural dimensions play an essential role to create new knowledge, including mathematics (Rosa, et al. 2016).

From the development of human civilization, some experts have said that local people had mathematical knowledge (Dehaene 2011). It may be seen in their traditional structures all across the world. There are many instances where people have used mathematics as a tool to complete tasks. People on Java Island have constructed important structures like the Prambanan Temple, the Borobudur Temple, and other exquisite old structures. The Torajas of Sulawesi Island are renowned for their exquisite Tongkonan houses. (Manurung 2017). The cultural structures erected by several other tribes all around the island. These structures exhibit a mathematical aesthetic, particularly in their geometric designs.

The accomplishments would not have been feasible without intuitive mathematical concepts. To make dwellings horizontally balanced, for example, measuring the area and volume of buildings is essential. It is necessary to be able to approximate the relative location with its foundation utilizing knowledge of the perpendicular distance between two planes.

Other fascinating facts are that the local people in certain locations developed comparable models of buildings. Some tribes constructed traditional homes with triangular prism roofs. These patterns imply that diverse locals had similar ideas while creating houses and shared geometrical principles like "intuitive mathematics ideas." (Chen and Ja'faruddin., Traditional Houses and Projective Geometry: Building Numbers and Projective Coordinates 2021).

Examining traditional house shapes enables the interpretation of intuitive mathematical skill in house representation. Thus, the concept of projective geometry could help the formulation and codification of traditional Houses. Chen & Ja'faruddin (Chen and Ja'faruddin., Mathematics use in Indonesian's Traditional Buildings 2019, Chen and Ja'faruddin., Traditional Houses and Projective Geometry: Building Numbers and Projective Coordinates 2021) developed simple houses theory based on affine and projective geometry. Affine geometry and projective geometry are mathematical explanations of reality based on parallel projections and, respectively, human eye viewpoints. (Brannan, Esplen and Gr 2012). They are the foundation of the new concept of building numbers and projective coordinates (Chen and Ja'faruddin., Mathematics use in Indonesian's Traditional Buildings 2019, Chen and Ja'faruddin., Traditional Houses and Projective Geometry: Building Numbers and Projective Coordinates 2021).

Building numbers and projective coordinates were developed to identify traditional dwellings from Indonesia and other countries. Projective geometry is distinct from Euclidean geometry, which is taught in junior and senior high schools.

The concept encourages Students to understand mathematical principles while visiting traditional homes. House theory can provide insight into the mathematics that surrounds them. Understanding the shape of one structure may encourage students to use mathematics in their daily lives. Students can learn to categorize traditional architecture and apply geometric projection. This concept gently introduces students to a branch of mathematics that different from Euclidian geometry.

**Affine Geometry and Projective Geometry**

Affine geometry is a kind of geometry by affine transformations in which a parallel projection preserves its properties from one plane to another.

Definition 1

An affine transformation of $\mathbb{R}^2$ is a function
$t : \mathbb{R}^2 \to \mathbb{R}^2$ of the form $t(x) = Ax + b$, (1)
where $A$ is an invertible 2× 2 matrix and $b \in \mathbb{R}^2$ (Brannan, Esplen and Gray 2011).
The fundamental theorem of affine geometry

Let $p, q, r$ and $p', q', r'$ be two sets of three non-collinear points in $\mathbb{R}^2$ then (a) there is an affine transformation $t$ which maps $p, q$, $r$ to $p'$, $q'$, $r'$, respectively; (b) the affine transformation $t$ is unique (Brannan, Esplen and Gray 2011).

Projective geometry is a type of geometry based on projective transformations that explains how the eye perceives "the real world" and how artists can achieve realism. A projective transformation preserves both incidence and collinearity(Brannan, Esplen and Gray 2011)

Definition 2:

A projective transformation is a function
$t: \mathbb{RP}^2 \to \mathbb{RP}^2$ of the form $t: [\, x \,] \to [\, Ax]$ here is real projective space, and $A$ is an invertible 3× 3 matrix.

We say that $A$ is a matrix associated with $t$.The fundamental theorem of projective geometry. Let $ABCD$ and $A'B'C'D'$ be two quadrilaterals in $\mathbb{RP}^2$ , then there is a unique projective transformation t which maps $A$ to $A'$, $B$ to $B'$, $C$ to $C'$, $D$ to $D'$.
Simple House Theory.

The structures of traditional houses in Indonesian were used to establish the building numbers and projective coordinates. Traditional dwellings are represented in ethnomathematical terms by house designs, which are then projected and vanishing points are employed.

Definition 3

Let $\hat{A}_\alpha$ is the picture of a traditional house, and $\widehat{A'}_\alpha$ is a simple projection, called a house diagram, of the house onto a plane, where $\alpha$ is the number of vanishing points. (Ja'faruddin 2022)


*Figure 1. (a) Traditional house $\hat{A}_1$ from one vanishing point*
*(b) House diagram $\widehat{A'}_1$*

Based on the definition of projective transformations, the combination of a triangle and trapezoid is projective congruent with a rectangular triangle (Figure 2)

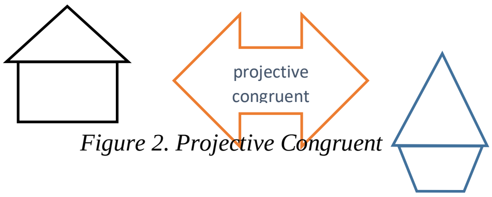



*Figure 2. Projective Congruent*

Building numbers were created using this definition. The classification rule was used to organize these simple house categories.. The categorization of simple houses was based on basic geometrical figures such as rectangles, triangles, the combination of rectangular triangle shapes, rectangular shapes, rectangular–triangular trapezoid shapes, rectangular trapezoid shapes, and shapes with curved edges. In this article, there are seven types of simple house category, which are Simple House I (Cubic Simple House),Simple House II (Triangular Simple House), Simple House III, Simple House IV, Simple House V, Simple House VI, Simple House VII (Paraboloid Simple House) (Chen and Ja'faruddin., Traditional Houses and Projective Geometry: Building Numbers and Projective Coordinates 2021, Chen and Ja'faruddin., Mathematics use in Indonesian's Traditional Buildings 2019)

Definition 4

The building numbers of a house diagram $\widehat{A}'_{\alpha\_\beta}$ are in the form of $\hat{n}_{\alpha\_\beta}$, where $\alpha$ is the index of a building of the same type, $\beta$ is the number of vanishing points, and n is a natural number.

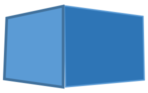
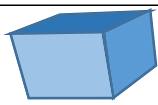
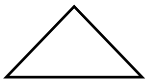
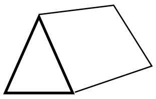
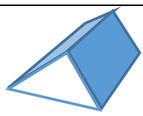
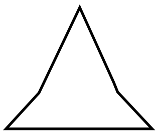
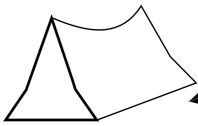
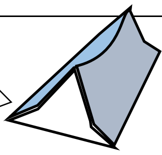
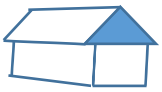
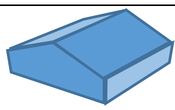
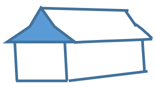
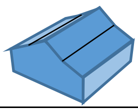
In this article, n = 1, 2, 3, 4, 5, 6, and 7.

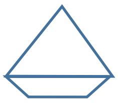
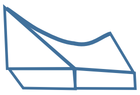
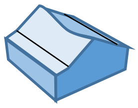
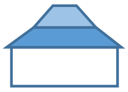
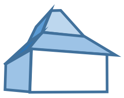
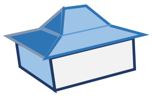
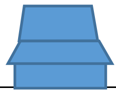
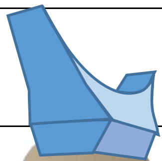
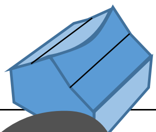
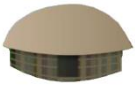
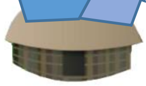
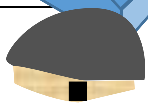
Projective coordinat. The concept of projective coordinates must be introduced to identify a traditional house model. Then, this concept can be applied to other traditional houses from Indonesia and other countries.

Definition 5: $(a, b, c)$ denotes the projective coordinate of a house diagram, where $a, b, and\ c$ are building numbers from one vanishing point, two vanishing points, and three vanishing points, respectively. Theorem 1: If A and B are simple houses, A and B have the same projective coordinates if they are projective congruent.

Below is the summary of the basic concept of Simple House Theory

Table 1. Summary of simple house categories' Building numbers and projective coordinates

| *The type of Simple house.* | *House Diagram* | | | *Projective coordinates* | *Example* |
|---|---|---|---|---|---|
| | *One vanishing point $(\alpha = 1)$* | *Two vanishing point$(\alpha = 2)$* | *Three vanishing point $(\alpha = 3)$* | | |
| Simple House I (Cubic simple house) |  |  |  | $(\hat{1}_{1\_1}, \hat{1}_{1\_2}, \hat{1}_{1\_3})$. |  A Mud House In Pakistan *Image By Tasawer Khan via flickr* |
| Simple house II |  |  |  | $(\hat{2}_{1\_1}, \hat{2}_{1\_2}, \hat{2}_{1\_3})$ |  Uma Lengge, Indonesia |
| Simple house III |  |  |  | $(\hat{3}_{1\_1}, \hat{3}_{1\_2}, \hat{3}_{1\_3})$ |  Batak Toba House, Indonesia Bola Soba, Indonesia |
| Simple house IV | |  |  | $(\hat{4}_{1\_1}, \hat{4}_{1\_2}, \hat{4}_{1\_3})$ |  |
| Simple house V | |  |  | $(\hat{5}_{1\_1}, \hat{5}_{1\_2}, \hat{5}_{1\_3})$ |  Bola Mario Indonesia |

| *The type of Simple house.* | *House Diagram* | | | *Projective coordinates* | *Example* |
|---|---|---|---|---|---|
| | *One vanishing point* $(\alpha = 1)$ | *Two vanishing point* $(\alpha = 2)$ | *Three vanishing point* $(\alpha = 3)$ | | |
| Simple house V |  |  |  | $(\hat{5}_{1\_1}, \hat{5}_{2\_2}, \hat{5}_{2\_3})$ |  Batak Toba |
| Simple house VI |  |  |  | $(\hat{6}_{1\_1}, \hat{6}_{1\_2}, \hat{6}_{1\_3})$ |  Joglo House, Indonesia |
| |  |  |  | $(\hat{6}_{1\_1}, \hat{6}_{2\_2}, \hat{6}_{2\_3})$ |  Tongkonan, Indonesia |
| Simple house VII (Paraboloid simple house) |  |  |  | $(\hat{7}_{1\_1}, \hat{7}_{1\_1}, \hat{7}_{1\_1})$ |  Hanoi House, Indonesia |

## METHOD

Data was gathered through documentation, observations, and interviews. Camera images, aerial camera photos (drone camera), and documentation techniques were used to observe numerous traditional buildings in Indonesia for projective geometry and traditional houses. The traditional house samples were taken from West Nusa Tenggara (Nusa Tenggara Barat), Wajo, Bone and Sidrap Indonesia. All the samples are traditional houses with terraces erected on poles, Aerial photography was used to capture images of traditional structures from above and on the sides..

## RESULTS AND DISCUSSION

### Projective Geometry and Affine Geometry

Figure 3 presents two images of Buginese traditional houses from different perspectivity. The points $P, Q$ and $Q$ are points in the first image and the points $P', Q'$ and $R'$are in the second image,

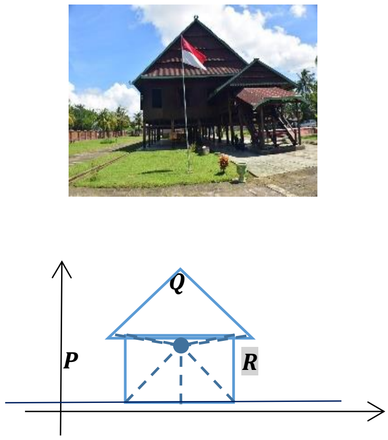
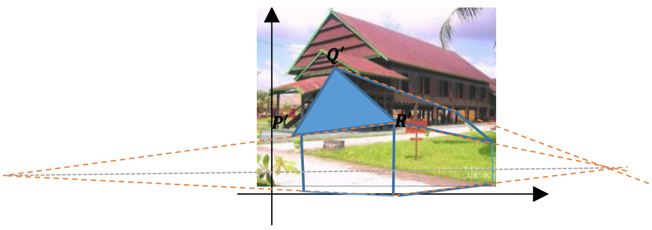



*Figure 3. An example of Affine transformation in traditional building*




The affine transformation which maps P, $Q$, R to $P'$, $Q'$, R' given by

$$t:\begin{pmatrix}x\\y\end{pmatrix}\mapsto\begin{pmatrix}a & b\\c & d\end{pmatrix}\begin{pmatrix}x\\y\end{pmatrix}+\begin{pmatrix}e\\f\end{pmatrix}$$

Figure 4 presents two images of Joglo house from different perspectivity. The points $p\ (0{,}3), q(5.4{,}7)$ , $r(5{,}3)$ and $s(7{,}7)$ are points in the first image and the points $p'(0{,}2), q'(7{,}2.8)$ , $r'(10.3{,}4)$ and $s'(9{,}8.4)$are in the second image.

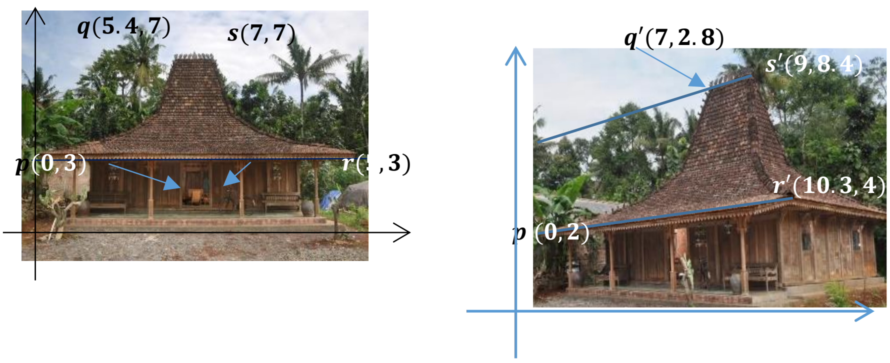



*Figure 4. An example of Projective transformation in Joglo House*

The homogeneous coordinates that correspondent to $p\ (0,3), q(5.4,7)$ , $r(5,3)$ and $s(7,7)$ are $[0,3,1], [5.4,7,1]$ , $[5,3,1]$ and $[7,7,1]$ repectively. Similarly, the points $p'(0,2), q'(7,2.8)$ , $r'(10.3,4)$ and $s'(9,8.4)$ are $[0,2,1], [7,2.8,1]$ , $[10.3,4,1]$ and $[9,8.4,1]$ respectively.

The required projective transformation is

$$A = \begin{pmatrix} -\frac{14663}{142} & -\frac{1476}{875} & -\frac{1172}{137} \\ -\frac{1565}{38} & -\frac{351}{530} & -\frac{1577}{587} \\ -\frac{15777}{1069} & -\frac{83}{576} & \frac{233}{400} \end{pmatrix}$$

**Simple House theory in some Buginese Traditional Houses**

1. Traditional house in NTB

*Figure 5. Traditional House In NTB*

This traditional house is located in Dorebara village, Dompu District, West Nusa Tenggara Province, Indonesia. The house was built in the style of vernacular architecture. The style and shape of the house are very simple; it was built by human instinct as a shelter from criminals, predators, and natural disturbances. The arrangement of the house's indoor and outdoor areas in simple impressions.

The picture of the traditional house has house diagrams as below

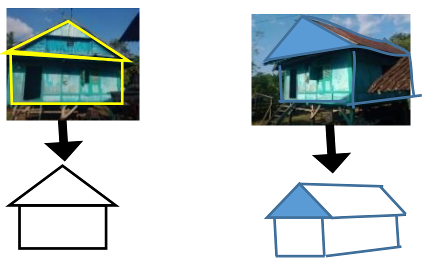


*Figure 6. House diagram for traditional house in Dorebara village*

Based on the house diagrams which are The shape of the house diagrams are combination between a triangle and a rectangle. so, the traditional house from NTB (West Nusa Tenggara) has building numbers and Projective coordinate $(\hat{4}_{1\_1}, \hat{4}_{1\_2}, \hat{4}_{1\_3})$, and chategorized as Simple house IV

1. Saoraja La Tenri Bali, Wajo, South Sulawesi

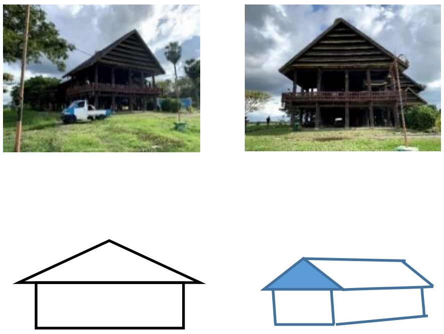


*Figure 7. House diagram for Saoraja La Tenri Bali*

Saoraja La Tenri Bali is Buginese traditional house, located in wajo District, South Sulawesi Provicen, Indonesia. Saoraja means place , and La tenri bali in the name one of King in Wajo Kingdom. Saoraja means palace in Bugis, and La Tenri Bali is the name of a former Wajo Kingdom Arung Matoa (King). Soraja La Tenri Bali is the Palace of King La Tenri Bali. The traditional house of Saoraja La Tenri Bali is a house on stilts. Unlike other Bugis traditional houses, the pillars of this house are round. The Saoraja traditional house is also known as the 101-pole House (Bola Seratue) because it is supported by 101 poles.

Figure 7 shows a house diagram of Saoraja La Tenri Bali. The house diagram in figure 7 above shows that the diagram of the traditional house is a combination of triangles and quadrilaterals. Thus Saoraja La Tenri Bali has building numbers$\hat{4}_{1_1}$ for one perspective ( one vanishing point), from two perspectives $\hat{4}_{1\_2}$ ( two vanishing points) and from three perspectives ($\hat{4}_{1_3}$three vanishing points) and so that the traditional house is categorized as Simple house IV and has a Projective coordinate$(\hat{4}_{1_1}, \hat{4}_{1_2}, \hat{4}_{1_3})$.

2. Bola Soba , Bone, South Sulawesi

Bola Soba are monumental structures for the Buginese. Terraces were used in the construction of this traditional home. The central section of this traditional house is

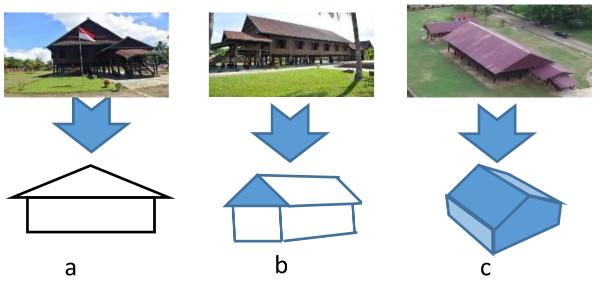



*Figure 8. Bola Soba's images*

Approximately 21 meters long, with an 8-meter-long backyard. Locals preserve these structures as historical, cultural, and museum structures. Bola Soba translates as "Friendship House." These houses were built to entertain, receive, and welcome honorable visitors from other kingdoms or countries.

Bola Soba is a simple house IV example. Figure 8 depicts three different perspectives of Bola Soba. Figure 8(a) depicts the front view of the Bola Soba, the one vanishing point, and its house diagram by ignoring the indentations or protrusions in the image of the building. The house diagram is made up of a triangle and a rectangle. Figure 8(b) shows a house diagram that combines the front and left sides of the house (two vanishing points), while Figure 8(c) shows a house diagram that combines three parts of the house.

3. Carawali Village, Sidrap District, South Sulawesi, Indonesia

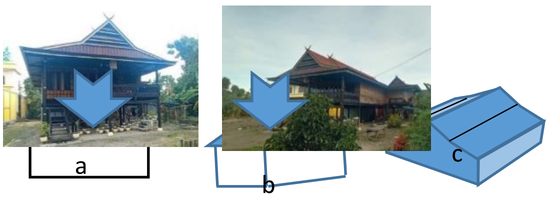



*Figure 9. Buginese Traditional House Style in Carawali*

Figure 4 displays the traditional house from two different perspectives. The house diagrams of this traditional house with two different vanishing points are presented with indentations and protrusions avoided. The house diagram of this house is simple house V.

Based on the picture above, the traditional house has building numbers $\hat{5}_{1\_1}$ from one vanishing point and $\hat{5}_{1\_2}$ from two vanishing points and $\hat{5}_{1\_3}$ from three vanishing points. The projective coordinate of this house is $(\hat{5}_{1\_1}, \hat{5}_{1\_2}, \hat{5}_{1\_3})$ which means that the traditional building is categorized as a simple house V .

## CONCLUSIONS

Based on the result and discussin, it can be concluded that

1. Traditional houses from Nusa Tenggara Barat, Wajo ( Saoraja tenri Bali) and Bone have *Building numbers* $\hat{4}_{1_1}$,for one *vanishing point,* $\hat{4}_{1_2}$ for two *vanishing points* $\hat{4}_{1_3}$ for three *vanishing points*. . These traditional buildings have projective coordinate $(\hat{4}_{1\_1}, \hat{4}_{1\_2}, \hat{4}_{1\_3})$. Thus the three of houses are *simple house IV*
2. The traditional house from Sidrap is categorized as *simple house V* with *the building numbers* $\hat{5}_{1\_1}$ from one *vanishing point,* $\hat{5}_{1\_2}$ from two *vanishing points* and $\hat{5}_{1\_3}$ *from three vanishing points*. This means that the traditional houses from Sidrap has *projective coordinate*$(\hat{5}_{1\_1}, \hat{5}_{1\_2}, \hat{5}_{1\_3})$

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