Traditional measurement units: a study on the construction of *rumah gadang* of Minangkabau

R Fitriza¹,²*, T Turmudi¹, D Juandi¹ and Y Harisman¹,³

¹Mathematics Education Department, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia
²Tadris Mathematics Department, Faculty of Tarbiyah and Keguruan, UIN Imam Bonjol, Jl. M. Yunus Lubuk Lintah Padang, Indonesia
³Mathematics Education Department, STKIP PGRI Padang, Jl. Gunung Pangilun, Padang Utara, Padang 25000, Indonesia

*rozifitriza@uinib.ac.id

**Abstract.** *Rumah gadang*, a traditional house of Minangkabau people, a tribe in Indonesia, is a form of manifestation of the knowledge of that ethnic which has unique architecture. The design and the construction of *rumah gadang* are traditional craftsman creation. This article presents a study on measurement which employs the process of constructing and measuring a *rumah gadang*. Using ethnography method, information was gathered from *tukang tuo* as a traditional craftsman. Identified from the interview, *dapo* (fathom), *eto* (cubit), *jangko* (span), *tampok* (a hand), and *jari* (finger), are the measurement units that are used by traditional craftsmen. Using non-standard measurement units, therefore, can be recommended for the teachers in their instruction in mathematics classroom in West Sumatera.

1. **Introduction**

West Sumatra (known as Minangkabau) is a rich area in culture and customs. One of Minangkabau culture elements which is outwardly appear as its trademark is *rumah gadang*. *Rumah gadang* Minangkabau is a kind of house on stilts which is physically large and consists of several rooms. The hallmark of a very prominent from *rumah gadang* is its curved roof shape and towers at both ends, then when it is viewed from the front sides, it resembles a buffalo horn called *gonjong*. Therefore, *rumah gadang* is also called *rumah gonjong*.

The process of traditional construction of *rumah gadang*, especially its architecture is inseparable from the traditional carpenter role which is locally named *tukang tuo*. How they translate the philosophy of Minangkabau tradition into the beautiful geometric forms. *Tukang tuo* generally do not take a formal architecture school. However, they only entered basic formal education until a junior high school level (preliminary interview). But exploring the "everyday cognition" of the activity and the people into an interesting study is performed. Exploratory research in ethnomathematics is useful for transferring formal knowledge in school to situations outside school and otherwise. In addition, researchers criticize the conventional cognitive theory using socio-cultural theory and practical theory. For the purpose of exploration, research (arithmetic process) has been conducted on tailor, child food vendors, food stuff sellers, bookmakers and carpenters [1]. Therefore, it becomes an important and interesting thing to explore the process of mathematical thinking from *tukang tuo*. 
Ethnomathematics studies for traditional houses had been done by Soares, explored geometric concepts in Mozambique's traditional house [2] Seroto, revealed mathematical concepts of the traditional buildings of Limpopo Province and the implementation at school [3], Putrie, identified mathematical concepts for instance area, line position, reflection, traditional regulation on traditional houses construction of indigenous villages of Kuta Ciamis [4], and Darmayasa, Wahyudin, Mulyana, finded multiple linear regression in post construction of Saka Roras traditional house of Bali [5].

The purpose of this research was to explore the mathematical ideas used by tukang tuo in the design and construction of rumah gadang. This paper focused on discussion to the size and measurement used by tukang tuo in the construction of rumah gadang. Then it could be used as a reference for teachers in learning measurements with the ethnomathematics teaching approach.

2. Method
This study applied an ethnography method. In essence ethnographic research, it emphasized on documentation and described the daily experience of the individual by observing and interviewing them [6]. The research design used in this research referred to ethnomathematics research conducted by Alangui. Ethnomathematics research was built based on four basic questions: Where to start looking? How to look? How to recognize that someone have found something significant? How to understand what it is? [7]

This research covered three regencies in the mainland of Minangkabau which are traditionally named as Luhak and known as 'Luhak Nan Tigo': Luhak Tanah Datar, Luhak Agam, and Luhak Limapuluh Kota. The subject is rumah gadang colored by traditional Minangkabau architectural characteristics, which already more than 100 years old. Participants in this study were the traditional carpenters (tukang tuo) of rumah gadang. The researcher interviewed 12 tukang tuo in the Luhak nan Tigo area, to obtain information on the design and construction process of rumah gadang.

3. Result and discussion
As a symbol of traditional custom, rumah gadang has several functions. Rumah gadang is not only a place to live in, but has more function as a symbol of the presence of community, the center of life, the discussion many things and the place to held various types traditional ceremony (turun mandi (“baby bathing”), wedding, batagak pangulu (promotion for the clan leader), and carrying for family members who get disease [8,9].

The various functions and types of harmony customs are generally influence the shape and size of a rumah gadang. Mathematical aspects related to the size of rumah gadang refers to the use of non-standard units. In designing the length and the width of the traditional house, tukang tuo uses size of bundo kanduang (the oldest mother in a family) body parts or size of tukang tuo body parts. The units of measure used includes dapo (fathom), eto (cubit), span, tampok (the length of hand that is stacked and closed), and fingers. The units of measure can be seen in the following of figure 1:

![Figure 1. The unit of length in rumah gadang.](image)

The use of non-standard units in measurement was used before humans knew the international standard unit. Measurement is one of the mathematics principles application in everyday life. Measurement bridges between geometry and real numbers, which uses the concept of numbers in practical activities. When the learners studied estimates and sizes using non-standard units, they simultaneously see the disadvantages of using non-standard units, understanding why a standard unit required [10].
Some tukang tuo (in Luhak 50 kota) believed in ‘tajuruba’ the traditional science in determining the size of the house, where the length, width and height of the house should be an odd number. For example, the length of the house is 18 eto, width is 12 eto, height is 8 eto, and the sum of all the sizes is 38 eto. This is not allowed, because the number of length, width and height is even. If the number of length, width and height of a house has even numbers, they believe that the house was not good to live in. Furthermore, the amount of the size was reduced by 35 eto, that was 38 eto - 35 eto equals 3 eto. On the other words, for the size of length, width and height, it should be exaggerated or reduced not exceeding 3 eto.

Besides using the principle of ‘tajuruba’, there are some other rules used by tukang tuo in determining the size of rumah gadang. Here are some rules to be used: the area (length times width of the house) was an odd number. The height of rumah gadang should be 1 to 3 of the length (Used by tukang tuo in Luhak Agam). Another tukang tuo in Luhak 50 Kota believes that the ideal size of rumah gadang is that if the width of the house is at least ½ (a half of) the length of the house.

It could be seen that tukang tuo understand the concept of numbers, simultaneously using approximation and comparison skills in measurement. The proportion of the building is found automatically by tukang tuo. The proportion of buildings is also influenced by climate factors.

The length of rumah gadang is determined by the amount of rooms since it related to the number of daughters owned by a family. This unique tradition is influenced by the matrilineal descent system in Minangkabau, so rumah gadang belonged to the women. Referring to Rapoport, there are five aspects that affect the shape of a dwelling house, namely needs, family, women, privacy, and social relationships. Rumah gadang, essentially, has fulfilled these five elements, it is not only limited for a private space, but also as a public space that allows social interaction [11].

Based on the length of room, rumah gadang is divided into two that are: rumah gadang panceuang talang (length of room to shrink to tip) and rumah gadang rueh tabu (length of room enlarged to tip) (tukang tuo, 2016). Rumah gadang panceuang talang, the length of the room is formulated as follows:

\[
R_1 = R - d_t,
\]
\[
R_2 = R - d_t - satampok,
\]

**Rumah gadang rueh tabu**, the room length is formulated as follow:

\[
R_1 = R_2 = R + d_t
\]

with R (the middle room) = 4 – 6 cubits, \(d_t\) = tonggak tuo diameter.

The width of the house is determined by the number of lanjar. In general, according to the principle enrolled in Tanah Datar, the number of lanjar rumah gadang is four pieces; biliak, bandua, labuah and balai, while rumah gadang in Luhak Agam and Luhak 50 Kota mostly have three lanjars. The size of the lanjar is does not always have same length. Rumah gadang gajah maharam and rumah gadang sitinjau lauik, besides the form its gonjong, also differed in the length of lanjar. Based on information from tukang tuo, the lanjar size of each type of rumah gadang as the following:

Type of gajah maharam: The length of bandua = labuah = A + d_t

Type of sitinjau lauik: The length of bandua = labuah = A - d_t

with A = the length of biliak = balai = 3 – 5 cubits, \(d_t\) = tonggak tuo diameter.

Room and lanjar in rumah gadang could be seen in the figure 2, the floor plan rumah gadang with five rooms:
Figure 2. Floor plan of rumah gadang with five rooms.

The roof of rumah gadang uses wood materials which are lae (wooded horizontal direction) and kasau (wood vertical direction). The installation of kasau also has a rule in which kasau of a rumah gadang must be odd (21, 23, 25 pieces), with the distance between kasau with kasau about one cubit. While the installation of lae is with a distance of about 2-3 fingers (for roof made from ijuk).

The paran (above) curved is compatible to the curvature of the roof, resulting in outer posts (according to the long direction) having unequal height, as presented in the figure 3 below:

Figure 3. The position of the posts in front.

The high of posts formula was found as the following:

$$t_0 = C + D$$  \hspace{1cm} (6)

$$t_1 = t_0 + \frac{1}{6} d_i$$  \hspace{1cm} (7)

$$t_2 = t_0 + \frac{1}{5} d_i + satampok$$  \hspace{1cm} (8)

C = the height of under the house
D = the height from palanca to paran
$$d_i = tonggak tuo$$ diameter

The out of posts stand tilted with a slope of as far as the diameter of a post or ½ cubits -30 cm from an upright position. The slope of the post is intended to prevent the wall from impacting the rain. The slope of the post leads to the carvings of rasuak (wooden connecting post according to the width of the house) on the sloping of post was different from the others. It means that the sloping of post on the outer left and right was same, and then it was done by the way as the following figure 4:
Figure 4. Measurement of the outer slope of the post.

*Tukang tuo* hung the ropes at the top of the outer post to the right with the ends that was given to the wooden weights. The rope would show the position perpendicular to the ground due to the influence of the gravitation from the earth. Furthermore, it is measured the distance from the rope to the base of the post using the *enau* or coconut leaves. The piece of the leaf became the size *balabeh* for the slope of the left outer post. The use of straps or leaf is for *balabeh* in length, helped and facilitated *tukang tuo* to work. *Tukang tuo* implemented the Minangkabau philosophy, ‘*Alam takambang jadi guru*’ (learning from nature). A number of activities of various professions in a cultural group have their own ways make measurement. The use of traditional measuring tools such as part of body or pieces of wood/rope is still used by the community [12,13].

Each of *rumah gadang* post stands on a flat stone, called *sandi*. Its function is to avoid the post form an easy decay because it was not directly in contact with the ground. In addition, it also prevents the post to sink into the ground, if there was a construction on soft soil. Traditional craftsmen today put the laying at the same place toward *sandi* before the posts are set up, it means that the length and width of the house form is a rectangle. Forming a rectangle with right angles especially right-angled requires: one of sides is measured along 60 cm, the threads are installed. Hereinafter, on the other side stretched yarn is lengthening for 800 cm, then it is made a piece of wood, 1 metre length. If the position of the yarn and wood forming the triangle has been fitted then it is obtained the right-angled, as a benchmark form a rectangle in preparing *sandi*. In the past, artisans used size 3, 4 and 5 spans for size 60 cm, 80 cm and 1 metre as a triple Pythagoras. This is reflected in the measure activities which are based on objects, and the estimate based on cultural activities carried out for generations [14].

*Rumah gadang* is a house on stilts with the result as it needs a stair to sustain the building inside and outside. The stair is made of wood, although there is a house built in 1891 already use stone steps. The number of stairs must be odd, 3, 5, 7 or 9. The distance of the rung is adjusted to the number of stairs that it is desired. To determine the position of the stairs, the carpenter measures the length of the main wood using the yarn, or the *enau* leaves, and then the yarn or leaf or the length of the staircase is divided into 3, 5 or 7 parts according to many stairs. For stone staircase, the width of the stairs is 35-40 cm, assuming the average of the human foot length is 30 cm, so there should be more 5 cm forward and 5 cm backward, for the convenience when walking down the stairs. The distance between stairs is 30 cm. Many stairs are influenced also by the height under the house. The height under the house is adjusted for its use by a house, whether as an animal cage, a place for weaving, or a storage area only.

4. Conclusion
The use of non-standard units in the size of *rumah gadang* and its parts, as well as the rules that the builders are believed to be applicable in each of these measures, becomes as guidelines for the next generation of Minangkabau traditional architecture. The formulation for the size of the length of room, the length of the *lanjar* or the height and the slope of the post was found by *tukang tuo* based on previous experience, as it is seen the traditional architecture of *rumah gadang* according to ‘*alua jo patuik*’
(custom and beauty rules). Mathematical ideas used by tukang tuo in designing and construction of the rumah gadang can be used to measurement learning with ethnomathematics teaching approach in school.

Acknowledgments
Thank you to Dr. Ir. Syamsul Asri was on the reference regarding methods and the existence of tukang tuo in Luhak nan Tigo. I would like also to thank tukang tuo, thank you for the time and sharing knowledge was about the traditional architecture of rumah gadang.

References
[1] Millroy W 1991 An Ethnographic Study of the Mathematical Ideas of A Group of Carpenters Journal for Research in Mathematics Education 5 1–221
[2] Soares D B 2009 The Incorporation of the Geometry Involved in the Traditional House Building in Mathematics Education in Mozambique: The Cases of Zambezia and Sofala Provinces (University of the Western Cape: Dissertation)
[3] Seroto N M 2012 Mathematical Concepts of the Traditional Building of the Limpopo Province that Can be Used to Teach High School Mathematics (North-West University: Thesis Doctor of Philosophy)
[4] Purtietis M 2014 Study Ethnomathematics Mengungkap Konsep-konsep Matematika Pada Aturan Adat dalam Aktivitas Pembangunan Rumah Tradisional Masyarakat Kampung Kuta Kabupaten Ciamis Jawa Barat (Universitas Pendidikan Indonesia: Skripsi)
[5] Darmayasa J B Wahyudin Mulyana T 2018 Ethnomathematics: The Use of Multiple Linier Regression Y = b1X + b2X2 + e in Traditional House Construction Saka Roras in Songan Village Journal of Physics: Conf. Series 948 012076
[6] Fraenkel J R, Wallen N E, Hyun H H 2012 How to Design and Evaluate Research in Education (New York: Mc-Graw-Hill)
[7] Alangui W V 2010 Stone Walls and Water Flows Interrogating Cultural Practice and Mathematics (New Zealand, University of Auckland: Doctoral Disertation)
[8] Navis A 2015 Alam Takambang Jadi Guru Adat dan Kebudayaan Minangkabau (Padang: PT Grafika Jaya Sumbar)
[9] Asri S 1996 The Design Construction and the Meaning of Traditional House in Minangkabau, West Sumatra Seminar: Traditional Dwellings in Western Indonesia and Ways of Their Inhabitation Leiden 28-29 March 1996
[10] Janet A 1991 Is there any mathematics in measurement? Teaching and learning school mathematics 69-76
[11] Rapoport A 1969 House Form and Culture, Foundations of Cultural Geography Series (California: Prentice-Hall)
[12] Owens K and Kaleva W 2007 Changing our perspective on measurement: A cultural case study Mathematics Essential Research Essential Practice 2 571-580
[13] Sirate S F 2011 Studi Kualitatif Tentang Aktivitas Etноматематика dalam Kehidupan Masyarakat Tolaki Lentera Pendidikan 14 2 123-136
[14] Muhtadi D Sukirwan Warsito and Prahmana R C I 2017 Sundanese Ethnomathematics: Mathematical Activities in Estimating, Measuring, and Making Patterns Journal on Mathematics Education 8(2) 185-198