Contemporary challenges of the Indonesian vernacular architecture in responding to climate change

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Abstract. Indonesian traditional architecture commonly called vernacular architecture has a wide range of local wisdom in responding to the climate. With their philosophy to life in harmony with nature and proficiency, they created building performance and material usage which play as ‘a breathing building’. With supported by green open spaces surrounding the building, it indicates that indoor and outdoor thermal comfort could be achieved throughout the day. However, life has changed followed by changes in the building materials especially in roof covering materials. Although the building form and orientation may have not changed, the indoor and outdoor climate has practically increased, whereby temperature change has also resulted from climate change as global events. To understand its impacts on the material changes, a method applied in this research was to compare the use of artificial/prefab and natural roof covering materials from the existing Indonesian vernacular buildings, and then was analysed into the descriptive analysis based on architectural and green building principles. From this point, it could be highlighted as the contemporary challenges for today and the future. Therefore, a result of this research is to prove that any change, in particular, the use of building materials from natural to artificial materials in the Indonesian vernacular buildings will increase the indoor temperature which finally lead to the user's discomfort.

1. Introduction
Indonesia has been inhabited by hundreds of tribes with various cultures and traditions including its architecture as part of culture. The richness of traditional Indonesian architecture with various forms and cultural identities can be observed from the westernmost island stretch (Sumatra) to the eastern tip (Papua) as part of the Indonesian archipelago. This stretch of the island from west to east, also makes a difference in time and also the local climate. Although there are differences in the local climate by performing different building shapes, their response to the climate is generally very good. The use of natural materials such as the main construction of wood, planks/ woven bamboo walls, thatched roofs, bamboo/ wood, and others, are materials that are very helpful in obtaining thermal comfort inside and outside the building as they have low conductive heat. In addition, the dimensions and orientation of the buildings are carefully regulated by them in utilizing air circulation and avoiding solar thermal radiation, and rainfall which sometimes have a large volume.

However, over time, the rapid development of technology in the building sector has been followed by changes in attitudes and life style of the people who support it. Because of this, the existence of traditional Indonesian architecture, which is often classified as vernacular architecture, has undergone changes not only in the use of building materials but also in its dimension and building orientation. Material changes generally occur in the use of the main structure, followed by some parts of the building such as; floor, wall and roof covering materials. Although the material changes have taken place in some
Indonesian vernacular buildings, several Indonesian tribes still maintain the values and appearance of the original building, in particular for those who have an adequate development budget. The material changes mostly caused by limited natural material resources and high cost. As a consequence, apart from the issue of cost, the change in the use of building materials and structures in Indonesia’s Vernacular buildings has a direct effect on increasing temperatures inside and outside the building besides due to climate change as global warming.

With the increase in temperature in the indoor, this has implications for residents trying to maintain a comfortable indoor temperature with temperature control equipment such as air conditioner (ac), fan, or exhaust fan. This equipment not only adds to the financing of tires on the buildings, especially maintenance costs, but also reverse the philosophical concept of vernacular Indonesian buildings to the environment. The change in the use of passive (natural) systems to active (mechanical) systems in Indonesian vernacular buildings has resulted in carbon dioxide production which is no longer friendly to the surrounding environment. On this issue, a research carried out at this stage was to highlight the impacts of the indoor temperature change in the use of building materials between the original and artificial/prefab materials on the existing Indonesian vernacular buildings. Through this comparison, it could be summarized the impacts of the building indoor temperature in relation to the indoor thermal comfort for the residents. As a result, the aim of research is to prove that any change, in particular, the use of building materials from natural to artificial materials in the Indonesian vernacular buildings will increase the indoor temperature which finally lead to the user's discomfort.

2. Literature Review

Several sources of information as a literature review are taken to help and clarify the purpose of this study. Literature review encompasses 1) Indonesian vernacular architecture, 2) Tropical climate regions, and 3) Thermal & building comfort.

2.1. Indonesian vernacular architecture

The term vernacular is derived from the Latin vernaculus, meaning "domestic, native, indigenous"; from verna, meaning "native slave" or "home-born slave". The word probably derives from an older Etruscan word [1]. According to Ladd [2], vernacular architecture has a simple definition in which architecture is without architects. It responds to a particular person’s or society’s building needs. It fulfils these needs because it is crafted by the individual and society. In addition, methods of the building are tested through trial-and-error by the society of which they are built until their building methods near perfection and are adjusted to the climatic, aesthetic, functional, and sociological needs of their given society. Meanwhile, Heath [3] states that vernacular architecture represents a localized response to broad cultural systems, historical events, and environmentally determined regional forces. As such, vernacular architecture often points to an observable condition of dynamic cultural and environmental change; it speaks of transition rather than stasis. It marks a liminal period, a threshold of conscious change and accommodation expressed in built form, whereby simultaneous identities result.

Furthermore, vernacular architecture refers to buildings built by people or society who took into consideration their requirements, societal conditions, environmental factors and materials. One could formulate a discourse tracing the intellectual development of a given society's history through a systematic study and analysis of its vernacular buildings. The form of a people-built environment is the form of their culture, and that building form is the result of thousands of little acts contributed by generations to generations [4-7]. Because the vernacular building relates to their culture and traditions, it is meant that the diverse traditions of architectural practice reveals that all vernacular architecture has a cultural base [8-14]. Every architectural tradition is a tradition of attitudes towards a socio-cultural system, and each tradition is different to the extent that the underlying culture is different in its hierarchy of values. Architecture is a language of cultural expression [15-18]. It is one of the means that the members of a society employ to express society and its values in the physical world [19].
2.2. Tropical climate regions
According to Gut and Ackerknecht [20] tropical climate as Indonesia Regions is characterised by high rainfall and high humidity. The range of temperature is relatively high which is around 30-35°C and is fairly even during the day and throughout the year. Because of the differences in minimal temperature, winds are light or even non-existent for longer periods. Whereas, heavy precipitation and storms take place frequently. From other source, weather online has similar statement to Paul Gut that the main variable of Indonesia’s climate is not temperature or air pressure, but rainfall. Split by the equator, Indonesia has an almost entirely tropical climate, with the coastal plains averaging 28°C, the inland and mountain areas averaging 26°C, and the higher mountain regions, 23°C. The area’s relative humidity is quite high, and ranges between 70 and 90 percent. The extreme variations in rainfall are linked with the monsoons. There is a dry season (June to September), and a rainy season (December to March). Western and northern parts of Indonesia experience the most precipitation, since the north- and westward-moving monsoon clouds are heavy with moisture by the time. Western Sumatra, Java, Bali, the interiors of Kalimantan, Sulawesi, and Irian Jaya are the most predictably damp regions of Indonesia, with rainfall measuring more than 2,000 millimetres per year [21].

The tropics with all 12 months of the year have temperatures above 18 °C. The three types of tropical climate are classified as Tropical Rainforest or Equatorial (Af), Tropical Monsoon (Am) and Tropical Wet and Dry or Savannah (Aw). But the climate of Indonesia Regions is dominantly influenced equatorial and monsoon climates. The equatorial climate is characterised by hot average temperature all year round and high monthly precipitation, typically no less than 60 mm a month with annual precipitation tending to be over 200 0mm. The diurnal temperature range is greater than the annual temperature range. The general pattern of the tropical climate is warm temperatures. Depending on the type of tropical climate, humidity is variable with Equatorial climates experiencing large quantities of precipitation all year round and Tropical Wet and Dry and Tropical Monsoon climates experiencing seasonal shifts in rain patterns [22]. Whilst according to Rosenlund [23] adds that minimum average monthly temperature is above 18°C and sub classes are defined by differences in seasonal rain fall distribution. A warm-humid or tropical climate has a fairly constant temperature, both over the day and over the year. Humidity and cloudiness make diffuse solar radiation important, and the potential for radioactive sky cooling is lower. Seasons are of - ten determined by rain fall and winds.

2.3. Thermal and building comfort
Comfort is closely related to wellbeing, which was defined by O’Brien et al [24] as “…when individuals have the psychological, social and physical resources they need to meet a particular psychological, social and/or physical challenge”. Hence, wellbeing incorporates other factors such as employment and relationship status, rather than just physical comfort within an environment. Furthermore, according to ASHRAE, thermal comfort is commonly defined as the “condition of mind that expresses convenience with the thermal environment” [25]. Meanwhile, another definition is the absence of thermal discomfort that an individual feels neither too warm nor too cold. The temperature of this state is referred to as the neutral temperature. However, thermal sensation is subjective, meaning that not all people will experience comfort in the same thermal environment. For indoor conditions, comfort zones are typically implemented to satisfy 80% of people [26]. The comfort zone is often expressed as a temperature range around the neutral temperature. Outdoors, the thermal comfort range is wider than in doors, spanning from thermal comfort to a stressful environment [27-28].

3. Research method
The research approach applied was a qualitative research, in which the research aims to address the impacts of the building indoor temperature on the Indonesian traditional buildings after changing its main materials. A comparison between the use of original and artificial/prefab materials on the traditional buildings are fundamental in this research. By using a qualitative method and case study, the method of analysis could be selected and set out. The research location was in the Indonesia tropical regions in terms of energy performance, thermal comfort of occupants and cultural acceptance. To
achieve the certain objectives, relevant data and information was collected through text-based research and in situ observation. The case study was selected on the Indonesian traditional houses deriving from three different islands in Indonesia that are Sumatra, Java, and Bali. Each island was represented by one traditional/vernacular building by careful selection. The vernacular houses selected for case studies have a complete information derived from the availability of literature, different building performances, ethnics and islands. Those are: Batak Toba Traditional House (North Sumatera), Sundanese Traditional House (West Java), and Balinese Traditional House (Bali), in which the house’s locations are in one row of islands.

4. Result and discussion
This section is systematically divided into two subsections as results and discussion. The results of the study are some data collection presented in figures, whilst the discussion is to analyse the result of the study into a descriptive analysis.

4.1. Results
Due to most parts of data derive from literatures, webs, and articles, data collected in this research for analysis are by taking some images from considerable evidence. Since the data analysis will compare between traditional/vernacular and modern buildings (after material changes), two images of both the buildings are shown as a result of the survey.

4.1.1. Batak Toba traditional house. One of the most well-known house buildings in Sumatera Island is Batak Toba traditional house whereby the house has wide indoor space. The house is commonly called Rumah Bolon, which is rectangular form and can be occupied by 5 to 6 families. To enter the house we have to climb a ladder located in the middle of the house, with various odd steps. If people want to enter the Batak Toba house, they must bow their head so they do not hit the transverse beam. This means visitors must respect the home owner. The base of the house is often built 1.75 meters above the ground, and the lower part is used for the pen for pigs, chickens, and so on [29]. The door to the house has two types of doors, namely horizontal and vertical doors. But now, horizontal leaflets are not used anymore. The room in a traditional house is an open space without rooms, even though it is inhabited by several families, but that does not mean there is no division of areas, because this is adjusted to the division of residence of the house which is regulated by their strong custom [30]. Furthermore, a linier pattern was used to place their house which is opposite to their granary. With rectangular shape in which its long side is towards the north south axis, hence the house has an orientation to the south as the main entry of the house (Figure 1). Meanwhile, the recent building changing the original roof covering with zinc/steel sheet as figure below will be discussed at discussion stage (Figure 2)

![Figure 1. Layout of a linier housing pattern of Batak Toba traditional house](image-url)
Figure 2. The images of Batak Toba traditional house [29]

4.1.2. Sundanese traditional house. The house has a compact shape, with the small open porch, the core space is often undivided. The kitchen is included as a living room family gathering. The house is built on a pedestal or house on stilts with a height of 40 - 60 cm. Traditional building materials made of wood or bamboo as framework and wall materials. For roofs they are generally used fibres. The space under the neat is functioned as a place to maintain fat animals like chickens, duck or to save agricultural tools. The basic support of house poles made of stone. Besides that, it can also be made of a brick arranged. While wall is part of the house serves as a boundary between indoor and outdoor. This part is made from woven bamboo and wooden material called gabyog. Window that serves to regulate the exchange of air from indoor and outdoor. Window is made of wooden planks in such a way so that air can freely escape. The wall’s bamboo or wood, is also used to cover the gable roof structure at both upper sides. Even though an axis of east-west is used to compose housing pattern, the main orientation of the Sundanese traditional house is to the South including the main entry of the house (Figure 3 and Figure 4).

![Figure 3. Layout of Sundanese traditional house pattern](image)

Figure 3. Layout of Sundanese traditional house pattern

![Figure 4. The images of Sundanese traditional house [31](image)](image)

Figure 4. The images of Sundanese traditional house [31]
4.1.3. Balinese traditional house. Traditional Balinese houses have several different types of houses according to their social status. The residence of the king will be very different from the house of the public. However, if we look at the typology of traditional Balinese houses in one unit, the differences in social status are almost similar. In one unit there are several pavilions forming a court yard pattern. Each building in one unit has a specific function with the different number of columns. In this context, the building taken as one of the cases in this study is the Bale Meten which is a pavilion for sleeping as its main function. Bale Meten is located in the north zone with east-west longitudinal so its main orientation is southward (Figure 5). The orientation of this meten building has similarities with the Sundanese and Toba Batak traditional houses.

![Bale Meten](Source: Author, 2009)

Bale meten building specification is a building supported by eight columns (small size buildings), 12 columns (medium size) and 16 columns for large sizes. With a minimum foundation height of 80 cm, this building has the highest elevation compared to other buildings in one unit. As well as a high foundation, the bed becomes an integral part of the building column in the inner room with the height of the bed about 55 cm above the floor of the building (Figure 5). Building walls made of mud are non-bearing walls; it only penetrates the inner space [32]. Compacted soil is used for the floor of the building. There are only widows on the south and north sides. Meanwhile, the main material of the roof is originally made of alang-alang grass (reeds) which is also as ceiling

4.2. Discussion

4.2.1. Building orientation. Building orientation is an important aspect in terms of building energy efficiency including passive systems. This is based on the statement from the world-famous architect of Norman Foster in which he illustrated [33]: “the choices available with a pyramid. At the top are the sophisticated and expensive active systems, such as photovoltaic panels. In the middle tier are passive systems, while at the bottom of the pyramid is orientation: how the building sits on the site and interacts with its surroundings”. Due to the key role of orientation in driving passive system of the building, it can be used as one of the most important criteria to evaluate the three Indonesian traditional buildings as cases above. If we look at the three cases of the buildings, only Batak Toba traditional building has a longitudinal form toward east and west whereby it means that the longitudinal form faces the sun as heat sources.

However, with their intelligence, the east and west sides of the building are without window and wide roof eaves to protect the building’s façade. As a result the sun heat transfer is not significant to
increase indoor temperature. In addition, the other sides of the building facing to north and south are created the higher roof as the building face hence showing an artistic roof form. Meanwhile, both Sundanese and Balinese traditional houses have an orientation to the South in order to achieve more daylight whilst avoiding solar radiation. From this point, the indoor temperature can be maintained well.

4.2.2. Building components. Building components mentioned in this stage are floor, wall, and roof which are philosophically as foot, body, and head. Roof as the building component is a most driving factor to influence indoor temperature as the roof receives solar radiation all day and rain water. As a consequence, the roof plays an important role in high or drop indoor temperature. Because of that, various shapes of roof were developed in Indonesia by the tribe to anticipate bad impacts of the local climate. Hip, cross hip, pyramid hip, gable, Dutch gable, high cone, and combination shapes have become popular roof forms of the Indonesian traditional houses. The Balinese traditional house uses hip roof with wide overhang and steep slope to accelerate rainwater falling down; the Sundanese house familiarly uses gable roof and some to use Dutch gable with a similar concept to the Balinese house in anticipating rainwater from the top. Whilst, the roof Batak Toba house uses the form of a gable that curves its upper plane which is a very attractive. This roof is also functional for anticipating the impact of local climate.

Meanwhile, the wall of the house as the building perimeter or façade in responding micro-climate depends on the usage of material which will be discussed later in building materials. Stilt houses constitute one of house building identities in Indonesia even in South-East Asia. All houses proposed as case studies uses stilts floor although Balinese house appears to use stone foundation, it uses the stilts floor inside of the building. From the three houses, Batak Toba traditional house uses rise floor by more than 1.5m from the surface, whilst Sundanese and Balinese stilts houses are lower than Batak Toba house. But if Balinese stilts house is measured from the surface including its foundation, the height of bed might be similar to Batak Toba’s stilts height. The concept of the stilts house derives from local wisdom in terms of responding local climate, since the space under the floor for wind circulation and taking air flow from there. As the result, it can help creating better indoor thermal comfort. Besides taking airflow from the underfloor, the stilts floor is also to avoid high evaporation from the ground.

4.2.3. Building materials. In relation to use passive system, the usage of building materials really determines in practices. As the Indonesian traditional house called as vernacular architecture, almost all the initial building materials derive from natural resources such as timber, bamboo, stone, mud, and palm and reed sheet. The main structure uses timber deriving from the forest near the site, the timber columns are placed on the stone, whilst palm or reeds sheets are specifically used for the roof covering. The different materials for the traditional house buildings as the case studies, take place in the use of wall materials in which Batak Toba uses timber for its wall, woven bamboo for Sundanese house, and mud for Balinese house’s wall. Even though there are the difference, the responses to microclimate are still good since all of that materials have low heat transfer. Hot outdoor temperature at noon does not significantly to influence the indoor temperature due to the low heat transfer from the building materials. Besides that, the inhabitants have activities at the outside from morning to afternoon, so that there is no negative impact for the inhabitants from the indoor temperature at noon. Therefore, indoor thermal comfort can be perfectly reached at night because warm air from the ground will rise to the floor while cold air enters through the gaps in the roof covering.

4.2.4. Impacts of material and climate change. Today, the change of building materials for the traditional houses has taken place which is not only for Batak Toba traditional house, but also for the Sundanese and Balinese traditional houses. The change of lifestyle, development of technology, and globalisation are assumed to mostly influence the change of the building materials. The change in the materials use can be identified such as the use of roof covering, wall, and floor. For instance, the use of brick for roof covering even the use of zinc/iron sheeting whereby these materials have higher heat transfer than the original materials. These have led to the higher indoor temperature compared to the original materials.
The use of ceiling also can increase the indoor temperature rather than without the use of ceiling. Besides that, the global climate change leading the temperature rise has also caused the indoor temperature to be higher. Based on a research result, the indoor temperature was only 2 °C lower than the outdoor, it means the indoor temperature is sufficient high [29]. Individuals may think that there is a difficulty to maintain building materials from natural resources because of durability and limited resources for today, although they have perfect response in the building passive system. The solution developed to maintain the better indoor thermal comfort is to use active system by using air conditioner, fan, exhaust fan, and other devices. Consequently, one of the local wisdoms in creating intelligent building through promoting passive system has been disappeared.

5. Conclusion
Traditional Indonesian house buildings that are built vernacular are much influenced by the local climate or in other words, the local climate has played a very important role in the design of Indonesian vernacular architecture. It can be observed from the shape of the stage, the structural system, orientation and the use of the materials used. The inside and outside spaces are designed not only to meet their life activities but in an effort to provide comfort, especially for all residents in the building of their house. The use of timber, bamboo, palm sheets and other materials is a material that absorbs heat and emits it when the temperature drops so that it is able to provide good comfort. In addition, the stilts building as an identity of the Indonesian traditional houses is designed to respond to the microclimate. Air circulation under the floor of the building can help the indoor thermal comfort. Meanwhile, the use of a wide pyramid roof in an effort to anticipate high rains in the rainy season is a smart step in the design. The solution to the comfort of the inner and outer spaces has proven the intelligence of the traditional community in realizing the realm of their traditional house building.

However, due to changes in lifestyle and culture, advances in building materials, and cost efficiency, part of community supporters have changed their thinking in maintaining the importance of their traditional houses as their cultural identity. Of the three cases discussed, the Batak Toba traditional house has the biggest change in indoor temperature due to the use of zinc material as a roof covering which has a strong conductive heat so that it is very easy for the room to heat up. Meanwhile, in the Balinese traditional houses, there is only a slight increase in indoor temperature due to the use of brick tile as a roof covering which is much lower in heat conduction than zinc/steel sheet. Whilst, the Sundanese traditional house is a house that is still very strong in maintaining the use of natural materials. The change in the roof angle from the Sundanese house, which is more sloping, is actually better especially for houses located in mountainous areas, as the inside temperature is warmer at night when the outdoor temperature falls. Although some parts of their traditional houses have changed especially in the material usages, their building orientation as a key role in determining indoor thermal comfort still has been maintained well, whereby the keeping North-South axis as their main building orientation has shown their intelligence in achieving the indoor comfort.

References
[1] Merriam-Webster 2002 Merriam-Webster's concise dictionary of english usage (California: Merriam-Webster) p 799
[2] Ladd N 2003 What is vernacular architecture (Seattle: ARCH) p 420
[3] Heath K W 2009 Vernacular architecture and regional design (England: Routledge) p 210
[4] Johnson G A 1977 Aspects of regional analysis in Archaeology Annual Review of Anthropology 6 479-508
[5] Rapoport A 1980 Cross-cultural aspects of environmental design Environment and culture. human behavior and environment (advances in theory and research) Vol 4 ed. Altman I, Rapoport A, Wohlwill J F (Boston: Springer) pp 7-46
[6] Duncan J S (ed.) 1981 Housing and identity: Cross cultural perspectives (London: Holmes & Meier Pub.) p 250
[7] Maar P and Smith K 1983 *Home sweet home: american domestic vernacular architecture craft* (New York: Rizzoli Intl Publications) p 150

[8] Norberg-Schulz C 1979 *Genius loci: towards a phenomenology of architecture* Rizzoli (New York: Rizzoli Publisher) p 213

[9] Seidel A 1994 Knowledge needs the request of architects *Proc. of the 25th Annual Int. Conf. of the Environmental Design Research Association-EDRA* (Texas, USA) pp. 18-24

[10] Grabar O 2006 Cities and citizens: the growth and culture of urban islam *Islamic art and beyond vol III* (Hampshire: Ashgate Publishing Limited) pp 89-116

[11] Rapoport A 1989 On the attributes of tradition *Dwellings, settlements and tradition: cross cultural perspectives, USA and England* ed. Al-Sayyad N and Bourdij J. (Maryland: University Press of America) pp 77-106

[12] Mitchell W J 1990 *The logic of architecture* (Cambridge: MIT Press) p 304

[13] Hershberger R G 1988 A study of meaning and architecture *Environmental aesthetics* ed. Nassar J L. (Cambridge: Cambridge University Press) pp 175-194

[14] Kuban D 1983 Modern versus traditional: a false conflict *Mimar: architecture in development ed. Khan H U* (Singapore: Concept Media Ltd.) pp 54-58

[15] Rudofsky B 1964 *Architecture without architects* (Connecticut: Connecticut Printers, Inc.)

[16] Rapoport A 1969 *House form and culture* (New Jersey: Prentice Hall)

[17] Abel C 1982 Living in a hybrid world: the evolution of cultural identity in developing nations *J. Design Studies* 3(3) 127-132

[18] Norberg-Schulz C 1985 *The concept of dwelling: on the way to figurative architecture* (New York: Rizzoli)

[19] Lawrence D L and Low S M 1990 The built environment and spatial form *J. Annual review of anthropology* 19 453-505

[20] Gut P and Ackerknecht D 1993 *Climate responsive buildings: appropriate building construction in tropical and subtropical regions* (Switzerland: Swiss Centre for Development Cooperation in Technology and Management)

[21] Weather Online 2021 Diagrams for 2000 stations Available online: https://www.weatheronline.co.uk/reports/climate/Indonesia.htm

[22] The British Geographer 2021 The climate of tropical regions Available online: http://thebritishgeographer.weebly.com/the-climate-of-tropical-regions.html

[23] Rosenlund H 2000 *Climatic design of buildings using passive techniques* (Sweden: Lund University)

[24] O’Brien N, Lawlor M, Chambers, Breslin G and O’Brien W 2020 Levels of wellbeing, resiliency, and physical activity amongst Irish pre-service teachers: a baseline study *Irish Educational Studies* 39(3) 389-406

[25] Fountain M and Huizenga C 1997 A thermal sensation prediction software tool for use by the profession *ASHRAE Transaction* 103(2) 130-136

[26] McIntyre D A 1980 *Indoor climate* (London: Applied Science Publishers)

[27] Spagnolo J C and DeDear R J 2003 A human thermal climatology of subtropical Sydney *Int J. of Climatology: A J. of the Royal Meteorological Society* 23(11) 1383-1395

[28] Emmanuel M R 2005 An urban approach to climate-sensitive design: strategies for the tropics (London: Spon Press)

[29] Hanah H and Wonorahardjo S 2012 The architecture of Batak Toba: an expression of living harmoniously *Nakhara: J. of Environmental Design and Planning* 8 11-22

[30] Sitindjak R H I, Wardani L K and Nila Sari P F 2018 Form and meaning of Batak Toba house *Proc. 3rd Intl Conf. on Creative Media, Design and Technology* (Dordrecht: Atlantis Press) pp. 273-277

[31] Wahyudi A 2010 Perancangan bangunan tradisional sunda sebagai pendekatan kearifan lokal, ramah lingkungan dan hemat energi *Local Wisdom: Jurnal Ilmiah Kajian Kearifan Lokal* 2(1) 30-37
[32] Rajendra I G N A 2012 How a balinese traditional home creates a comfortable internal environment without resorting to energy usage Jurnal Kajian Bali 2(1) 41-56
[33] Crosbie M J 2000 Norman Foster: analog and digital ecology [Online] Available: http://www.architectureweek.com/2000/0927/news_2-2.html