Proceeding of International Conference on Multidisciplinary Research for Sustainable Innovation, Vol. 1 No. 1 (2024)
DOI to be assigned soon

Check for updates

Research Paper

A Model for Determining the Thermal Comfort of Fishermen's Houses on Coasts with Humid Tropical Climate

Andi Ahmad Fauzan Bachtiar[1]*, Baharuddin Hamzah[2], Idawarni Asmal[3], Nurul Jamala[4]
[1, 2, 3, 4] Hasanuddin University, Indonesia

Received : January 29, 2024	Revised : February 5, 2024	Accepted : March 9, 2024	Online : March 13, 2024

Abstract

Fishermen's houses on the coastal area of Dusun Karama Tengah, located at coordinates 119° 23' 0" with 119° 23' 9" BT, and 5° 13' 28" LS with 5° 13' 36" LS, with a humid tropical climate, has poor thermal comfort, and is not in the 22,8°C-27,1°C comfort category. Residents and house occupants feel stifled, hot, and uncomfortable during the day. Environmental factors, use of materials, construction, and the architecture of the fishing houses greatly contribute to the thermal comfort, apart from weather and climate factors. The aim of this research is to develop an innovative model for determining the thermal comfort of the fishermen's homes. This research uses survey methods and observations of several factors that contribute to the thermal comfort during the day. It also uses expert system analysis techniques, certainty factors, based on Geographic Information System (GIS). A total of 107 fishermen's housing units studied had poor thermal comfort, especially at 11:00-13:00 WITA or at 03:00-05.00 GMT. The poor thermal comfort of the fishermen's houses is because they do not apply the principles of eco-building, green-architecture, and the lack of: facade, overhang, insulation, trees and parks, as well as the large use of low-density building projects in the form of zinc and triplex ceilings. This research has not taken into account the level of heat reduction of the house materials and the environment, so it is expected to be done in the upcoming research.

Keywords: *Certainty Facto, Expert Syste, GIS, Thermal Comfort*

INTRODUCTION

Thermal comfort is a psychological and physiological subjective feeling sensation, which can vary at certain temperatures and circumstances, including health conditions (Zhang et al., 2023). Outdoor thermal comfort and indoor thermal comfort are each influenced by air temperature, solar radiation, wind speed, air humidity, insulation, clothing, activity, work rate and metabolic heat, air flow volume, building density, building height and vegetation (Barnabas et al., 1989), (Marialena Nikolopoulou, 2006), (Wijewardanea and Jayainghe, 2017), (Schneider, 2019), and (Idawarni Asmal et al., 2022).

Building thermal comfort has two main variables; temperature and relative humidity (Latif et al., 2019). Temperature and humidity are also influenced by the orientation of the building on the site, landscape design, healthy house design, sporty lifestyle, insulation on the facade, overhang width, ventilation availability, terraces, material and height of the ceiling, material and height of the plafond, as well as the number and material of furniture or furniture in the house (Jutraz, 2015).

Thermal comfort factors are climate factors such as air temperature, average radiation temperature, air relative humidity, air speed, and personal factors like activity and clothing resistance (Hidayat, 2017). To avoid unexpected thermal comfort >27.1°C (Kartika et al., 2021), and between 35°C-38.3°C (Hidayat, 2017), environmental and architectural engineering should be carried out by considering the geometry of the room, orientation of wind, sun, building materials, roof slope and landscaping (Talarosha, 2005) and (Latif et al., 2019). The average temperature at

Corresponding author's email: andiaan01@gmail.com

the equator is 35°C, including at the research location with high humidity reaching 85%, and the best temperature range for activities is 22.8°C-25.8°C, with 70% humidity (Talarosha, 2005).

Thermal comfort can be determined based on physiology, behavior and psychology of the occupants, through measuring thermal elements; indoor and outdoor temperature, wind speed and relative humidity (Nadir Bonaccorso and Graça., 2022). Factors that influence thermal performance (air temperature, wind speed, radiation temperature, heat transfer, ventilation openings and dimensions) will find the effect of openings on significant reduction of indoor temperature (Zhang et al., 2023).

Thermal comfort obtained from the previous research is based on SNI 03-6572-2001 (Handri et al., 2021), which says to be comfortably cool if the temperature is 20.5°C-22.8°C with relative humidity of 50%, optimally comfortable when the temperature is 22.8°C-25.8°C and relative humidity of 70%, and comfortably warm if the temperature is 25.8°C-27.1°C with 60% humidity (Handri et al., 2021). In addition, a house is said to have good thermal comfort if it is at a temperature of 20.5°C-27°C, otherwise it is said to be too cold or hot, as uncomfortable (Kartika et al., 2021).

The aim of this research is to develop an innovative model for determining the thermal comfort of the fishermen's homes. This research uses survey methods and observations of several factors that contribute to the thermal comfort during the day. It also uses expert analysis system techniques, certainty factors, mixture and spatial analysis based on Geographic Information System (GIS). Several previous studies related to thermal comfort focused more on measuring the elements of thermal comfort: humidity, air temperature, wind speed, radiation and solar orientation, land cover or vegetation and insulation separately. Not a single partial study was found that combined thermal comfort elements in a comprehensive and integrated architectural and environmental manner using expert systems and certainty factors. Apart from that, there is a previous research related to measuring thermal comfort which compares houses on the coast with houses in the mountains, the results shows that houses on the coast are more comfortable (Hermawan et al., 2015), and between traditional fishermen's settlements compared to fishermen's housing built by the government proves that traditional fishing settlements are more comfortable (Handri et al., 2021).

LITERATURE REVIEW

To avoid unexpected thermal comfort between 35°C-38.3°C or 95.0°F-100.9°F because it is uncomfortable (Hidayat, 2017), environmental and architectural modification was carried out by considering the geometry of the rooms, wind and sun orientation, building materials, roof slope, and landscaping (Talarosha, 2005) and (Latif et al., 2019). The average temperature at the equator is 35°C with high humidity reaching 85%, and the best temperature range for activities is 22.8°C-25.8°C, with humidity of 70% (Talarosha, 2005). The annual temperature of the rainy season on the coast is ± 23°C, in dry season at ± 38°C (Hermawan et al., 2015). Climate, air temperature, average radiation, air humidity, wind speed, and individual factors such as activity and clothing, all contribute to thermal comfort (Hidayat, 2017).

Thermal comfort can be determined based on: physiology, behaviour and psychology of the occupants, through measuring thermal elements; indoor, outdoor temperature, wind speed, and relative humidity (Hermawan et al., 2015). Factors that influence thermal performance (air temperature, wind speed, radiation temperature, heat transfer, ventilation openings and dimensions) will find the contribution of openings to a significant reduction in indoor temperature (Arifin and Hidayat, 2018). Building designs that are able to anticipate environmental conditions including the extreme ones like El Niño Southern Oscillation (ENSO) (McGregor and Nieuwolt, 1998), are buildings which can adapt to the surrounding climate, taking into account the quality of natural ventilation (Kalumata and Indarwanto, 2016) and (Song et al., 2022). With an ideal flow speed, the most efficient passive cooling provides a comfortable refreshing effect for the building occupants (Pratiwi and Arifin, 2021) and (Hadi et al., 2023). Significantly increasing thermal comfort in a room requires a behavioural strategy for efficient use of natural ventilation. Optimizing both materials and ventilation openings (Song et al., 2022), as well as maximizing thermal comfort, are beneficial for maintaining the occupants' health (Lin et al., 2023).

Energy efficiency behaviours include natural ventilation settings, material types, ventilation openings for windows, doors, curtains, shades, lighting, furniture and other interior equipment (Song et al., 2022). The use of natural ventilation can reduce energy consumption by 40%-50%, the behaviour of opening and closing windows, finding opening rules, building prediction and optimization models, become very important to improve the thermal comfort of a house or building (Song et al., 2022). Window opening behaviour was carried out in certain periods focusing on influencing factors, including: air temperature inside/outside the building, the model and area of window/ventilation, humidity, wind direction/speed, building orientation, roof/building material, number/activity of the occupants, the availability of trees/gardens, the thermal comfort of the building will increase by around 43% (Song et al., 2022).

RESEARCH METHODOLOGY

In conducting this research, quantitative descriptive analysis methods and techniques were used through surveys and observations, administrative and spatial data collection on research locations, architectural data on fishermen's houses, especially the material use, thermal comfort and environmental data on fishermen's houses and residential areas, administrative data related to population, number of household heads, activities of household residents, number of houses, schools, mosques and integrated service posts.

The spatial data was obtained through Google Earth in 2023, surveys and observations of 14 variables and 56 criteria related to the environmental data, including research location boundaries, land use, footpaths, fish landing areas, road access for vehicles and pedestrian path, the availability of: office, workshop, cultural heritage, mangrove forest, sea, river, catchment area, tree, people's harbor, building density, out card yard, pool and inner court. The architectural data for fishermen's houses includes the floor, wall, ceiling, roof materials, area of ventilation openings, availability of facades, wind catchers, chimneys, and insulation. While the thermal comfort data includes: air temperature, air humidity and wind speed. The tools used to measure the thermal comfort data were a Hobo data logger and an HTC-2 thermo hygrometer, while recording architectural data and construction of fishermen's houses with a camera.

The data that has been collected is processed using an expert system and certainty factors, analyzed using the GIS-based spatial data related to the model for determining the thermal comfort of fishermen's houses, especially living rooms during the day in Dusun Karama Tengah, Biringkassi Village, Takalar Regency, Indonesia, which is located in coordinates between 119º 23' 0"E and 119º 23' 15"E and between 5º 13' 28"S with 5º 13' 36"S. Expert system is a computer program that resembles human thinking and can even exceed it in solving problems and is part of the science of human intelligence (Mendea et al., 2022). The expert system consists of several rules which are prepared based on theory and knowledge or inference, consisting of several factors and categories which have a weight value according to the weight of influence and importance of the certainty factor (Lucas and Gaag, 1991) and (Mendea et al., 2022), as in Figure 1.

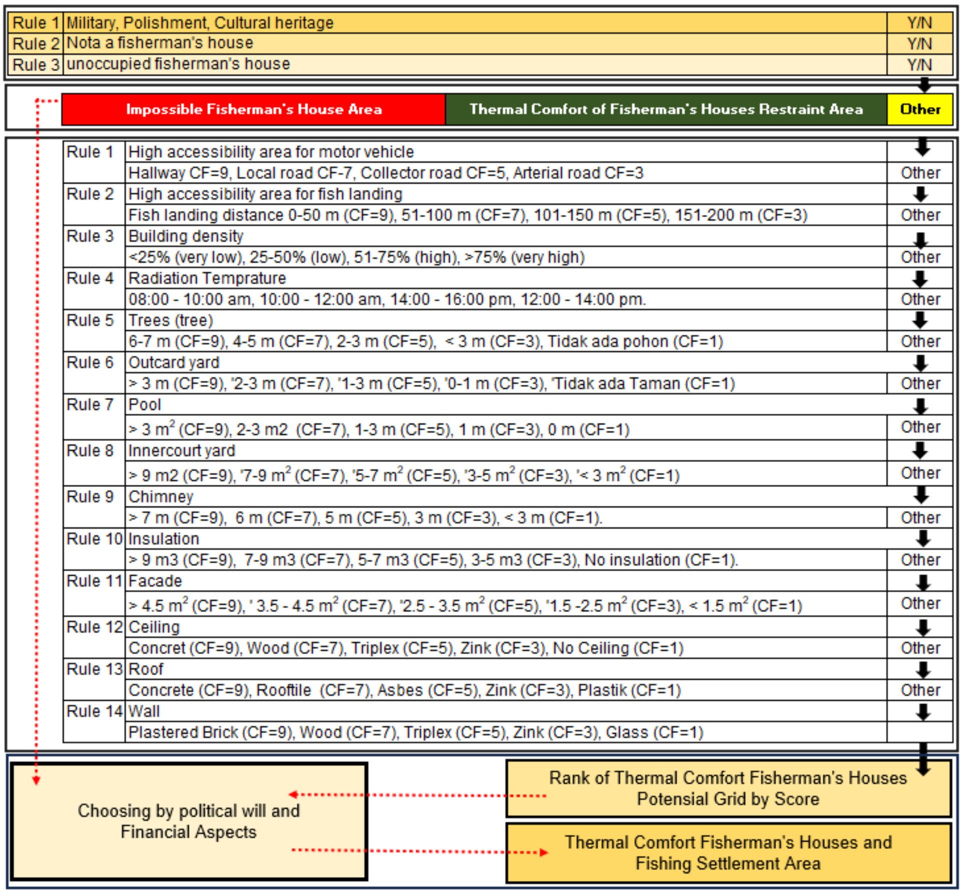


Figure 1. Expert System

After the expert system was composed with three possible fisherman's house area rules and 14 thermal comfort of fisherman's house restraint area rules, a certainty factor was created with 14 variables and 56 criteria, as in Table 1.

Table 1. Certainty Factors

No.	Factor	Category	CF	Code
1.	High accessibility area for motor vehicle	Hallway	9	HA
		Local road	7	
		Collector road	5	
		Arterial road	3	
2.	High accessibility area for fish landing	Fish landing distance 0-50 m	9	FL
		Fish landing distance 51-100 m	7	
		Fish landing distance 101-150 m	5	
		Fish landing distance151-200 m	3	
3.	Buiding density	<25% (very low)	9	BD
		25-50% (low)	7	
		51-75% (high)	5	
		>75% (very high)	3	
4.	Radiation temperature	08:00-10:00 am	9	RT
		10:00-12:00 am	7	
		14:00-16:00 am	5	
		12:00-14:00 pm	3	
5.	Trees (tree)	6-7 m	9	TR
		4-5 m	7	

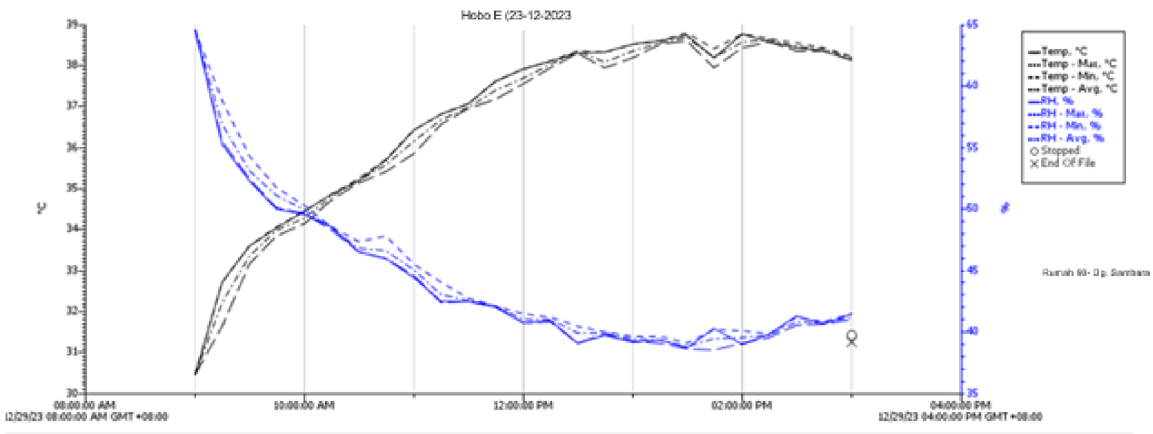
		2-3 m	5	
		<3 m	3	
6.	Outcard yard	> 3 m	9	OY
		2-3 m	7	
		1-3 m	5	
		<1m	3	
7.	Pool	>3 m	9	PO
		2-3 m	7	
		1-3 m	5	
		<1 m	3	
8.	Innercourt	>9 m^2	9	IY
		6-8 m^2	7	
		2-5 m^2	5	
		<2 m^2	3	
9.	Chimney	>7 m	9	CH
		6 m	7	
		5 m	5	
		<5 m	3	
10.	Insulation	>9 m^3	9	IN
		7-8 m^3	7	
		5-7 m^3	5	
		3-5 m^3	3	
11.	Facade	>4.5 m	9	FA
		3.5-4.5 m	7	
		2.5-3.0 m	5	
		<2.5 m	3	
12.	Ceiling	Concrete	9	CE
		Wood	7	
		Triplex	5	
		Zinc	3	
13.	Roof	Concrete	9	RO
		Rooftile	7	
		Spandek/Asbes	5	
		Zinc	3	
14.	Wall	Plastered brick	9	WA
		Wood	7	
		Triplex	5	
		Zinc	3	

FINDINGS AND DISCUSSION

Based on the house materials and environmental factors based on the expert system, certainty factors, and GIS-based spatial analysis, fishermen's houses have poor or uncomfortable thermal comfort. This thermal discomfort has been validated with the temperature measurements obtained from temperature the measurements of fishermen's houses, including the following.

Fisherman's house number 90 with poor thermal comfort or feels uncomfortable, namely those with temperatures >27°C measured during the day between 09:00 am and 03:00 pm (GMT+08:00). The measurement results show a thermal comfort at 10:00 am with a temperature of 34.30°C, air humidity 50%, minimum temperature at 30.45°C at 09:00 am (GMT+08:00) with air humidity of 64.63% and the maximum temperature was 38.79°C at 01:30 pm (GMT+08:00) with air humidity of 38.72%, which was uncomfortable as in Figure 2.

Figure 2. Uncomfortable thermal comfort graph of fishermen's house



The fisherman's house number 07 with poor thermal comfort or feels uncomfortable is at a temperature of 25.8-27.1°C measured during the day between 09:00 am and 03:00 pm (GMT+08:00). The measurement results show that the house is uncomfortable with a minimum temperature of 29.12°C at 09:00 am (GMT+08:00) with air humidity of 70.93% and the maximum temperature of 38.23°C at 12.30 pm (GMT+08:00) with air humidity of 41.43%, as shown in Figure 3.

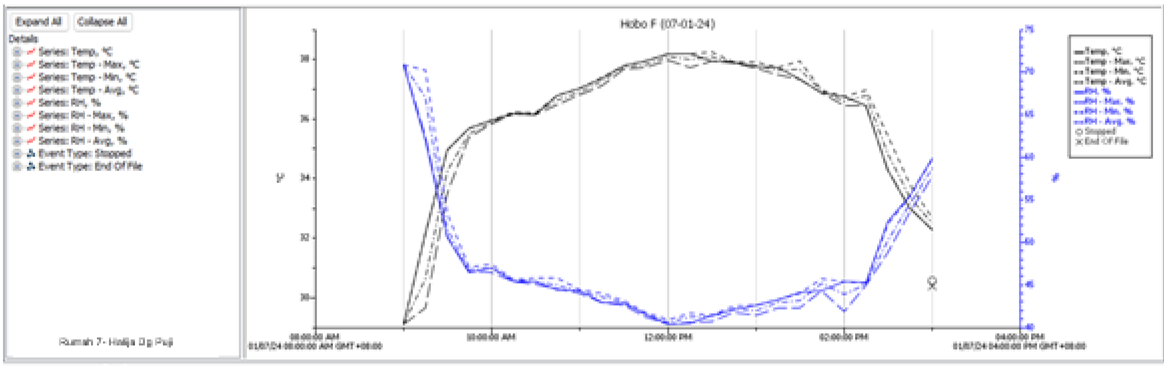


Figure 3. Uncomfortable thermal comfort graph of fishermen's house

The fisherman's house number 67 with good thermal comfort is at a temperature of 22.8-25.8°C measured during the day between 09:00 am and 03:00 pm (GMT+08:00). The measurement results show that the house has poor or uncomfortable thermal comfort with a minimum temperature of 28.69°C at 09:00 am (GMT+08:00) with air humidity of 75.61% and maximum temperature of 33.70°C at 03:00 pm (GMT+08:00) with air humidity of 67.56%. At 09:00 am the wind speed was 0.058 m/s, decreasing to 0.003 m/s at 10:45 am, to 0.00 m/s at 03:00 pm and changing back to 0.055 m/s at 16:15 pm until 04:30 pm the next day and continued to increase afterwards, as in Figure 4.

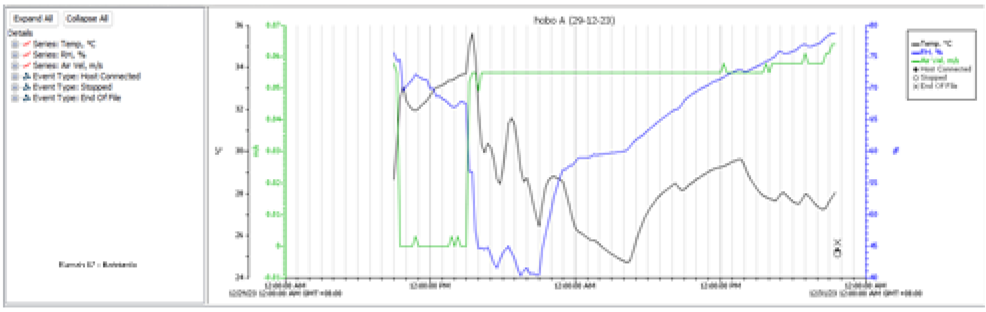


Figure 4. Thermal comfort graph of a comfortable fishing house

The fisherman's house number 80 with better thermal comfort or feels more comfortable is at a temperature of 20.5-22.8°C, measured during the day between 09:00 am to 03:00 pm (GMT+08:00). The measurement results show that the minimum temperature is at 29.64°C at 09:00 am (GMT+08:00) with air humidity 81.66%, wind speed 0.305 m/s, and maximum temperature at 32.17 °C at 12:45 pm (GMT+08:00) with air humidity 81.66% and wind speed of 0.305 m/s, as in Figure 5.

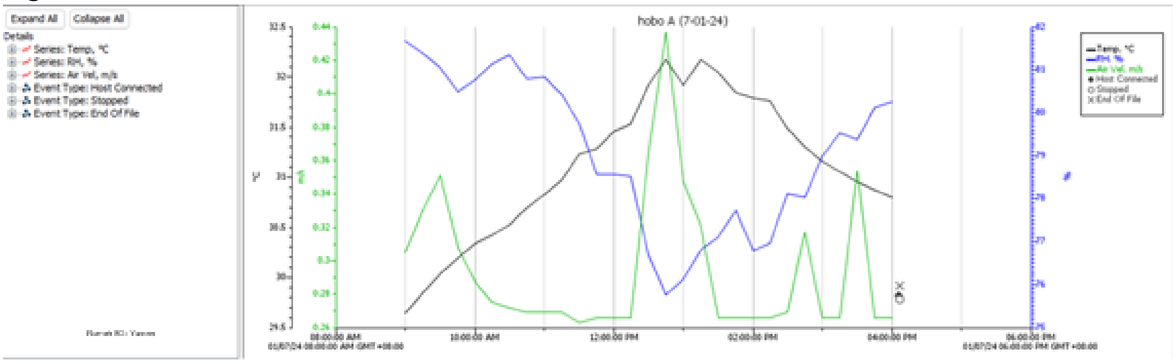


Figure 5. Thermal comfort graph for a more comfortable fishing house

Based on the results of temperature measurement, air humidity, wind speed and solar radiation, it was found that all fishermen's houses had poor thermal comfort with temperatures >27°C. The poor thermal comfort of the 107 fishermen's housing units is that there are still differences in the interval of potential thermal comfort values based on the certainty factors values, as in Figure 6.

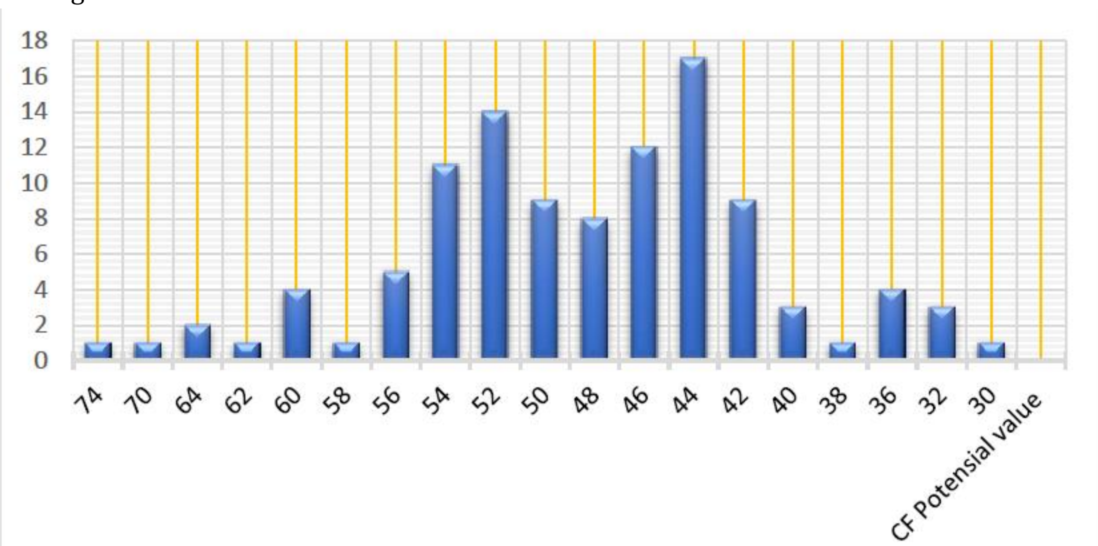


Figure 6. Graph of the number and potential values of thermal comfort

for fishermen's houses.

Based on the expert system, certainty factors, and the GIS-based spatial analysis; a thermal comfort map of fishermen's houses was obtained as in Figure 8.

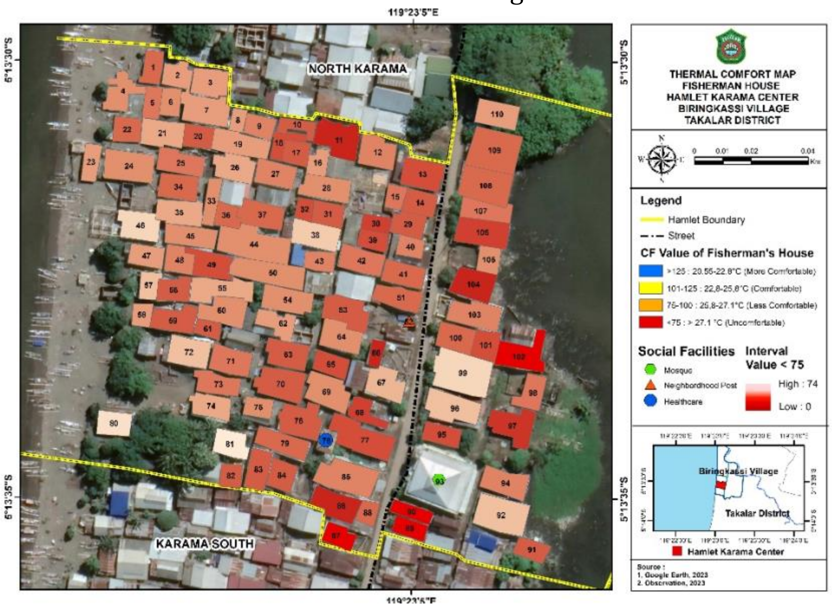


Figure 8. Map of thermal comfort of fishermen's houses

The difference in potential value is partly due to: 1) the house is in an alley, not around a highway which is polluted by vehicle heat radiation, 2) It is close to the sea and has a more comfortable thermal sensation because of the many trees and insulation, 3) It is located in an area that is not congested so that air circulation is good, 4) Has a garden outside the house, 6) Has a facade that eliminates solar radiation, 7) The ceiling and walls are made of boards which are good at resisting heat radiation, 8) The walls have ventilation openings, either in the form of breathing walls in stilt houses and ventilation openings in plastered brick houses which are quite cool because they comply with the principle of continuity and even though eco-coolers are still classified as having poor thermal comfort because the air temperature in the house exceeds 27°C as in Table 2.

Table 2. Thermal comfort of fishermen's houses

House number	Time	Radiasi (W/m²)	Air Velocity (m/s)	Humidity (%)	Temperature		Radiasi (W/m²)	Air Velociity (m/s)	Humidity	Time
					Min	Max				
90	09:00	017,9	0,03	64,63	30,45	38,79	106,8	0,06	38,72	13:30
07	09:00	014,9	0,31	70,93	29,12	38,23	104,1	0,30	41,43	12:30
67	09:00	011,9	0,06	75,61	28,69	33,70	118,0	0,00	67,56	15:00
81	09:00	008,4	0,30	81,66	29,64	32,17	048,1	0,30	81,66	12:45
08	09:00	025,1	0,37	75,41	27,80	37,48	028,1	0,49	56,46	14:15
62	09:00	018,3	0,00	79,97	29.76	33,03	025,6	0,00	72,37	14:15
72	09:00	008,2	0,06	66,99	28,25	33,58	030,3	0,00	58,77	15:00
46	09:00	011,9	0,00	75,44	29,95	33,87	028,3	0,00	59,38	14:15
74	09:00	009,9	0,04	75,41	27,80	37,70	014,3	0,59	56,46	13:30

Information:
At 09:00 am (GMT+08:00).

Based on the measurement data, it was found that the minimum temperature in fishermen's houses was 27.8-29.76°C at 09:00 am in the morning, and the maximum temperature was 32.17-38.79°C at 12:30-15:00 pm. The maximum air temperature in the fisherman's house is inversely proportional to the air humidity, and if the air humidity increases, the air temperature decreases, and vice versa. Relatively constant air humidity of 81.66% both in the morning at 09:00 am and 12:45 pm shows that the air temperature in the house is 29.64-32.17°C. The higher the wind speed and the greater the radiation temperature, the greater the difference between the minimum temperature and the maximum temperature. Because the temperature in the house exceeds 27.1°C, the fishermen's houses in Dusun Karama Tengah are all declared to have poor thermal comfort or not comfortable, whether using the Hobo data logger and HTC-2 thermo hygrometer or using the model for determining the thermal comfort of fishermen's houses.

CONCLUSIONS AND FURTHER RESEARCH

The poor thermal comfort of fishermen's houses is based on the expert system and potential house certainty factor values which have been validated by measuring temperature, air humidity, wind speed and solar radiation. It was found that all houses had poor thermal comfort. The cause of poor thermal comfort in a house is because the architectural elements of the house and its environment are poor, which are unable to reduce the heat of solar radiation. The fishermen's houses do not apply the principles of eco-architecture, eco-building, eco-cooling, and the principle of continuity. The materials used are easy to transmit radiant heat including zinc and spandex, do not use insulation or facades, do not have ceilings or only use materials with a small weight such as triplex, high building density, close to roads and the sea, no water pools, and lack of trees and parks (indoor/outdoor).

The next research is expected to accommodate more complete and more detailed architectural elements of the house, individual elements in the form of conditions and activities of the fishermen and their families as a source of heat. Apart from that, it is necessary to consider the optimal width of the house's ventilation openings, land functions, trees, shading, and other land cover elements that can absorb solar radiation and reduce the spread of hot air.

REFERENCES

Arifin, I. N. & Hidayat, S. (2018). Pengaruh bukaan terhadap kinerja termal pada Masjid Jendral Sudirman. *Vitruvian Jurnal Arsitektur, Bangunan, & Lingkungan,* Vol.7 No. 2 Februari 2018 Pages 67-76.

Barnabas, Boyden, Bugnicourt, Costa Leite, T. Deelstra, D. Djoekardi, Y. Hassan, F. K. Kloutse, A. Krtilova, K. Meguro, J. Michelsen & N. D. Peiris (1989). Health principles of housing. *United Nations Centre for Human Settlements (Habitat),* .

Hadi, D. S. N., Supriyanta & Wibowo, M. F. R. (2023). Efektifitas penghawaan alami dalam kenyamanan termal: Interfensi fasad dan teknologi eco-cooler pada ruang aula. *Sinektika Jurnal Arsitektur*

Handri, H., Sari, L. H., Munir, A. & Ariatsyah, A. (2021). An evaluation of indoor thermal environment in fisherman housing in West Sumatera. *IOP Conf. Series: Earth and Environmental Science 881 (2021) 012029*.

Hermawan, Prianto, E. & Setyowati, E. (2015). Thermal comfort of wood-wall house in coastal and mountainous region in tropical area. *ScienceDirect,* Procedia Engineering 125 725 – 731.

Hidayat, S. 2017. Faktor-faktor kenyamanan termal *SCRIBD*.

Idawarni Asmal, Baharuddin Hamzah & Ratna, H. (2022). Community response to thermal and its influence to outdoor use. *Civil Engineering and Architecture,* Vol. 10**,** 800-815.

Jutraz, A. (2015). How to design healthy building for healthy living? *Places And Technology.*

Kalumata, T. J. & Indarwanto, M. (2016). Pengaruh lebar sirkulasi terhadap aliran angin pada permukiman padat nelayan, studi kasus permukiman pasar ikan, Penjaringan, Jakarta Utara. *Jurnal Arsitektur Bangunan & Lingkungan, Vitruvian* Vol.5 No.3 Juni 2016**,** Pages 105-162.

Kartika, Q. A. Y., Hidayat, R. & Virgiyanto, R. H. (2021). Perubahan temperature humadity index *(THI)* di Pulau Jawa sejak 1981 hingga 2019. *Majalah Geografi Indonesia Vo. 35, No. 2, September 2021 (104-111)*.

Latif, S., Hamzah, B., Rahim, R. & Mulyadi, R. (2019). Thermal comfort identification of traditional bugis house in humid tropical climate. *Tesa Arsitektur Journal of Architectural Discourses,* Vol 17, No 1.

Lin, Y., Zhou, Y. & Chen, C. (2023). Interventions and practices using Comfort Theory of Kolcaba to promote adults' comfort: an evidence and gap map protocol of international effectiveness studies. *Systematic Reviews (2023)***,** 1-10.

Lucas, P. & Gaag, L. V. D. (1991). Principles of expert systems. *Centre for Mathematics and Computer Science, Amsterdam, published in 1991 by Addison-Wesley (copyright returned to the authors)*.

Marialena Nikolopoulou, S. L. (2006). Thermal comfort in outdoor urban spaces: Analysis across different European countries. *Building and Environment,,* Vol. 41**,** pp. 1455–1470.

Mcgregor, G. R. & Nieuwolt, S. (1998). Tropical climatology: An introduction to the climates of the low latitudes, 2 Nd Edition.

Mendea, H., Peters, A., Ibrahim, F. & Schmitta, R. H. (2022). Integrating deep learning and rule-based systems into a smart devices decision support system for visual inspection in production. *ScienceDirect Elsevier f32nd CIRP Design Conference* Procedia CIRP 109 (2022) 305–310.

Nadir Bonaccorso & Graça., G. C. D. (2022). Low-cost DIY thermal upgrades for overheating mitigation in slum houses in Latin America & Caribbean. *Energy & Buildings,* 271**,** 1-16.

Pratiwi, N. & Arifin, S. S. (2021). Analisis performa model eco-cooler sebagai alternatif bukaan alam. *Nasional Academik Journal of Architecture* Volume 8 Nomor 1,.

Schneider, G. (2019). Healthy housing environment in sustainable design. *IOP Conf. Series: Materials Science and Engineering 471 (2019) 092083*.

Song, J., Wang, W., Ni, P., Zheng, H., Zhou, Y. & Zhang, Y. (2022). Study on optimization method of summer nature ventilation for residential buildings in typical thermal zone of Xinjiang, China. *ScienceDirect* 8**,** 181–197.

Talarosha, B. (2005). Menciptakan kenyamanan termal dalam bangunan. *Jurnal Sistem Teknik Industri Volume 6, No. 3 Juli 2005***,** Pages 148-158.

Wijewardanea & Jayainghe (2017). Thermal comfort temperature range for factory workers in warm humid tropical climates. *Renewable Energy 33 (2008) 2057–2063,* Vol. 33**,** Pages 2057-2063.

Zhang, J., Lu, J., Deng, W., Beccarelli, P. & Lun, I. Y. F. (2023). Thermal comfort investigation of rural houses in China: A review. *Building and Environment 235 (2023)*.