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Thermal Investigation at Wonosobo Market, Indonesia

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***Abstract* -** Thermal comfort is one of the factors influencing the success of the building as a place of human activity. Market building in Indonesia plays an essential role in trading activity. The thermal conditions of the Wonosobo market have problems in realizing the thermal comfort of building users. This research aims to investigate the thermal situation of Wonosobo Market, Indonesia. The research method uses quantitative and qualitative methods. Measurements were made using an infrared thermometer. Subjective measures were carried out on 100 respondents. The results show that the Wonosobo Market building has not been able to meet the expectations of building users. The thermal performance of the Wonosobo Market needs to be improved to comfortably accommodate the activities of building users.
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Keywords – Thermal Comfort, Wonosobo, Market, Cold Climate, Subjective

Introduction

Indonesia is one of the countries that has a characteristic with the existence of traditional markets. Indonesian people are people who are happy with bargaining when doing shopping activities. The characteristics of the Indonesian people cause traditional markets to be widely used by the Indonesian people. The use of traditional markets as a place to shop makes the importance of research on market convenience. Comfort in a place has many kinds. One of the comforts that affect the success of activities is thermal comfort. Buildings are considered successful in accommodating human activities if they can create thermal comfort for building users. Thermal comfort can be measured by using temperature and CO2 content in the air (Asif & Zeeshan, 2020).

Temperature can be a reference in the fulfillment of thermal comfort for individuals. The formulation of a predictive model can measure the comfort the individual obtains to obtain a comfortable temperature for the individual. The comfortable temperature in each region differs according to the microclimatic conditions and the characteristics of the individual. In mountainous areas, it will be different from coastal areas, which have different microclimates (Hermawan et al., 2020). The comfortable temperature may vary for individuals with different activities. Research in the classroom found the individual's comfortable temperature below international, comfortable temperature standards. The difference is 5oC. The difference in comfortable temperature occurs due to various factors. Individual characteristics are very influential in making the comfortable temperature difference that occurs (Jiang et al., 2021).

Temperature measurement is carried out using a measuring instrument, either using a numeric thermometer or a light thermometer. Measurements are used for research that uses quantitative methods to obtain numerical results. Thermal comfort research can use quantitative or qualitative methods. The qualitative method is done by asking respondents to fill out a questionnaire (Stamatelopoulou et al., 2020). Qualitative research will fill in the gaps of quantitative research, which only reveals numbers. Research involving respondents directly will produce conclusions that are by the wishes of building occupants. Individual characteristics will be found related to the thermal comfort felt by building users (Hermawan & Prianto, 2018).

The results of filling out the questionnaire are subjective results from the respondents but can make input for building or architectural improvements. Changes in architectural elements will change the thermal comfort of building occupants. The relationship between architectural elements, especially the building envelope, is very closely related to the thermal performance of the building. (Hermawan & Švajlenka, 2021). Using building elements, both in terms of materials and the suitable form, is a strategy for building designers to create comfortable buildings. (Costa et al., 2019). Strategies to create good thermal performance buildings are carried out in many ways and with different disciplines. Chemical elements can be one of the elements used to create comfortable materials. Comfortable material research can use phase change materials (Gracia et al., 2016). Parametric methods and specific architectural approaches can also achieve optimization of the thermal performance of the building. The configuration of the building envelope is one way to create the thermal performance of the building (Abdel-Rahman, 2020).

It is essential to improve the thermal performance of buildings. A thermal investigation of a building will find the thermal condition of the building that can be used as the basis for increasing the thermal performance of the building. This study investigates thermal conditions in the Wonosobo market, Indonesia.

Method

Thermal comfort research was conducted using mixed methods. The quantitative method uses infrared camera measurements in the four cardinal directions. Infrared camera measurements get data on temperature and heat conditions in the four cardinal directions on the market side. In line with the measurement of temperature and heat, 100 respondents filled out questionnaires from market visitors—questions used as a questionnaire in the form of personal questions and questions about feelings towards thermal. Personal questions used as questionnaires are questions about age, height, and weight. Questions regarding place are about the length of time the respondent has been in the market. Questions about thermals are also related to clothing, so respondents were asked to complete a questionnaire about their clothes.

Questions related to thermal comfort are thermal sensation, thermal comfort level, air temperature comfort, humidity comfort, wind speed comfort, sun intensity comfort, environmental thermal comfort, and current thermal comfort. Questions about thermal adaptation are about activities carried out when it is cold and hot. The data analysis uses descriptive analysis, which explains the questionnaire results sent to the respondents. The results from the respondents can be concluded from the thermal conditions in the Wonosobo market. The public's perception of the thermal conditions of the Wonosobo market can be a measuring tool for building repairs in terms of thermal comfort.

Results and Discussion

Wonosobo Market is one of the big markets in Wonosobo Regency, Central Java Province. The Wonosobo market experienced a fire in 2018. At the time of the research, traders occupied the road around the Wonosobo market to sell. Market conditions not by their placement cause visitors and sellers to look less comfortable carrying out their activities. Circulation in the market seems to be poorly planned due to the fires. The placement of traders in the market looks uncomfortable in the wrong place (Fig 1).

Figure 1: Circulation in the market, a. West side of the market, b. East side of the market
Source: Author, 2022

Thermal conditions seen by using an infrared camera show that the air temperature is relatively high. On all sides, the average temperature value is between 28.5oC to 31.7oC. The temperature is more than the value of human thermal comfort in the highlands, which is predicted to have a comfortable value of 24oC (Hermawan et al., 2019). The condition of the Wonosobo market in the morning at around 9.00 WIB showed that the conditions were quite hot. The heat spread is mainly at the top because the tin roof used in the emergency kiosk makes the top thermal condition red. The infrared camera shows a blue condition at the bottom. Under certain conditions, the temperature appears to show a minimum temperature value between 23.1 to 24.4oC so that visitors can still look comfortable.

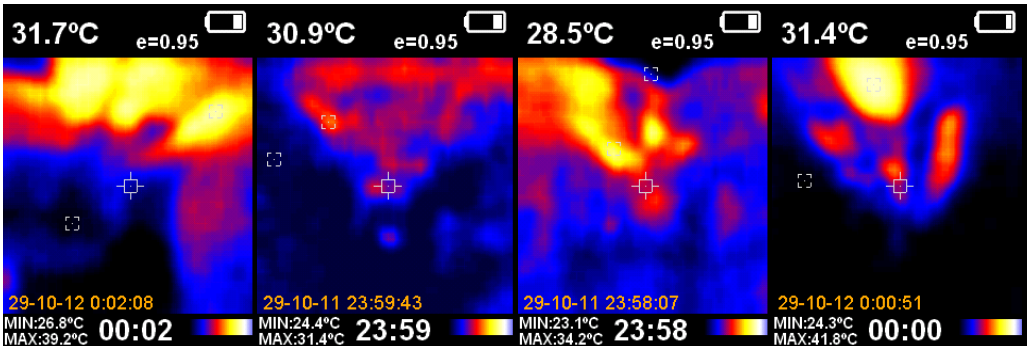

Figure 2: Thermal Visual at morning a. Northwest, b. Southeast, c. Southwest, d. Eastt
Source: author, 2022

During the day, the thermal conditions show that the temperature is classified as hot, with an average temperature of 31.1 to 32.8oC. The spread of heat is less visible, but the hot spots cause high temperatures in the market space. The minimum temperature reaches 26.8 while the maximum temperature reaches 35.7oC. Quite extreme temperatures occur on the southwest side of the market. The temperature is considered extreme because the Wonosobo region, as a mountainous area, often has low-temperature values. The daytime conditions during the study showed sunny and hot weather.

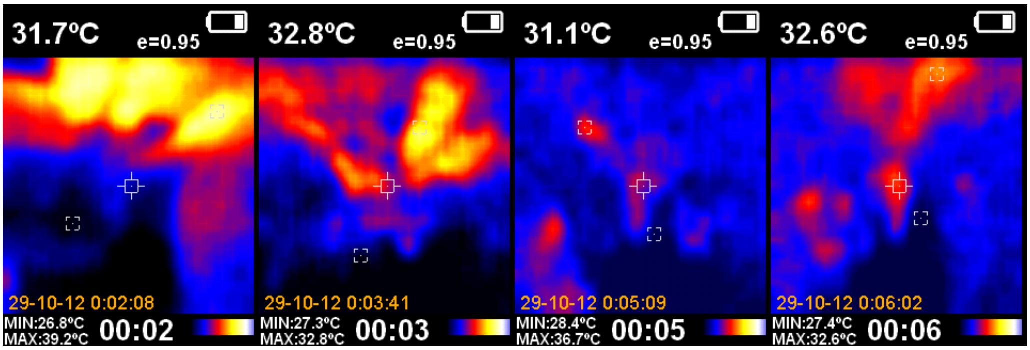

Figure 3: Thermal Visual at noon a. Northwest, b. Southeast, c. Southwest, d. Northeast
Source: author, 2022

The temperature in the market room in the afternoon looks lower than during the day, but higher than in the morning. The temperature has an average value range of 27.7-29.1oC. The minimum temperature reaches 25.2oC so that it is close to the comfortable temperature prediction of mountain communities (24oC). The maximum temperature is also not too high reaching 31.5oC. In the afternoon, the sun gradually sets and it often rains in Wonosobo City. The spread of heat obtained from the infrared camera is not visible because the sun is no longer stinging.

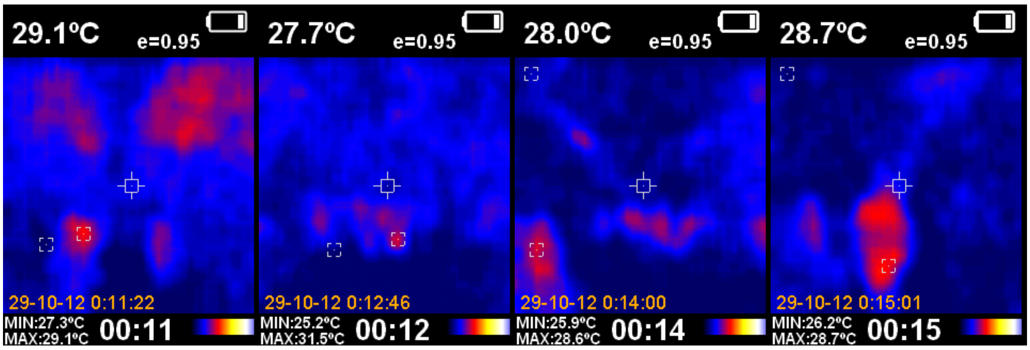

Figure 4: Thermal Visual at afternoon, a. Northwest, b. Southeast, c. Southwest, d. Northeast
Source: author, 2022

The research data is based on the total number of respondents who participated in this study, namely 100. Most of the respondents are in the age range of 40-60 years, then 19 percent are in the age range of 20-40 years, and 13 percent are in the age range of more than 60 years. The range of most respondents' height is between 150 - 160 cm, as much as 52%, and 160 - 170 cm, as much as 27%. Respondents who have a height between 140 - 150 cm as much as 11%, respondents with a height> 170 cm as much as 4%, respondents who have a height between 130 - 140 as many as 3%, and respondents who have a height < 130 cm as much as 3%. The weight range of most respondents was 50-70 kg, as much as 49%, weight 70-90 kg, as much as 42%, and weight 30-50 kg, as much as 9%. The percentage of respondents in place is between 60 – 240 minutes, or between 1-4 hours, which is 78%; this is because the survey was conducted between 09.00 – 13.00 WIB. Then respondents who were in place within a period of 240 – 360 minutes or 4 – 6 hours by 11%, respondents who were in place within a period of fewer than 60 minutes as many as 9%, and respondents who were in place within a period of > 360 minutes as many as 2%.

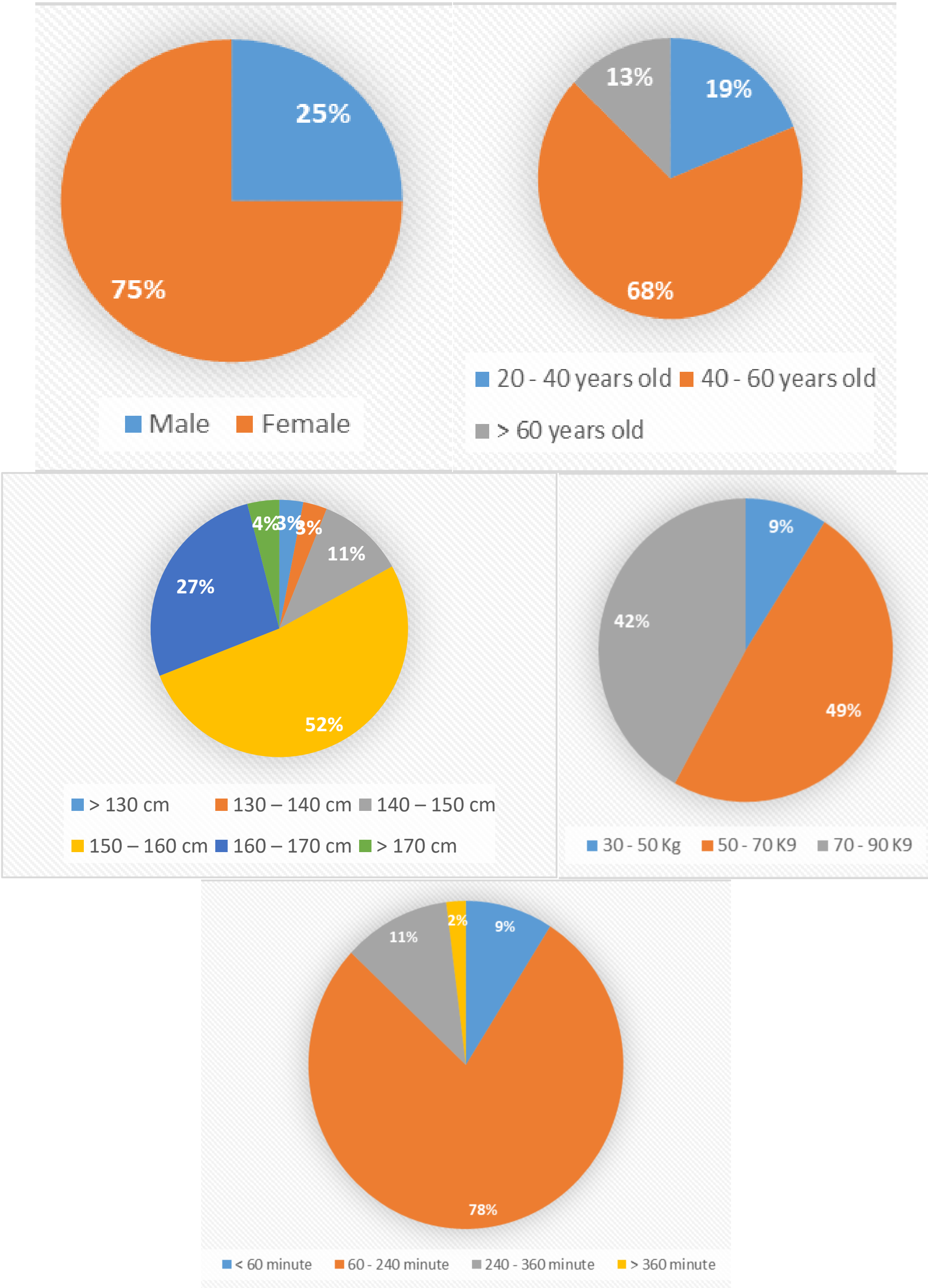

Figure 2: Respondent data, a. gender, b. age, c. height, d. weight, e. long time in place
Source: Author, 2022

As many as 70 percent of respondents wear clothes with long sleeves, 26 percent of respondents wear clothes with short sleeves, 4 percent wear jackets/coats, and 0 percent or none of the respondents wear short-sleeved clothes. Most respondents wore trousers as much as 61 percent and long skirts as much as 39 percent. None of the respondents wore shorts or short skirts. There are no respondents who do not wear footwear. As many as 90 percent of respondents wear sandals, and 5 percent wear shoes.

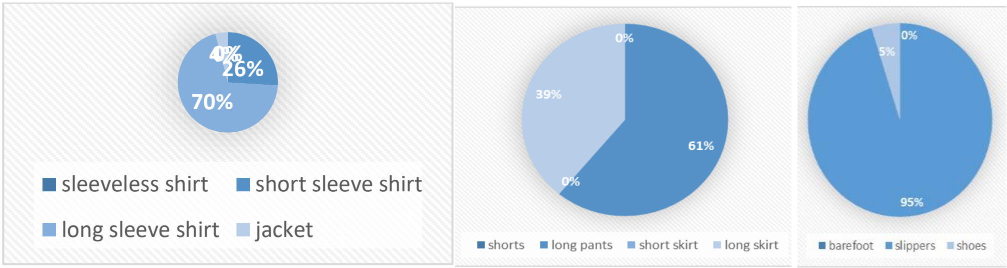

Figure 3: Respondent data, a.clothes, b.pants, c.footwear
Source: Author, 2022

Most respondents feel a neutral thermal sensation, which is 38 percent, while the number of respondents who feel hot and cold is the same at 22 percent. Respondents who feel warm and cold also have the same number, 9 percent. There are no respondents who feel the thermal is very cold or very hot. Respondents who felt comfortable and felt neutral about the thermal comfort of the Main Market Area at that time were 48 percent and 43 percent, respectively. At the same time, the remaining 9 percent felt dissatisfaction with the thermal comfort of the market area at that time. As many as 50 percent of respondents chose a neutral air temperature as their most comfortable temperature, while the remaining 26 percent chose cold and 24 percent chose hot. As many as 70 percent of respondents have felt neutral humidity, the remaining 21 percent want the humidity to be reduced, and 9 percent want the humidity to be more humid. As many as 90 percent of respondents chose a neutral wind speed, 9 percent wanted a faster wind speed, and 3 percent wanted a slower wind speed as the most comfortable wind speed. Respondents' responses to the sun's intensity were almost evenly divided into three groups. Namely, 36 percent wanted the sun's intensity to a dimmer, 33 percent wanted the sun's intensity to be brighter, and 31 percent considered the sun's intensity neutral. As many as 90 percent of respondents can receive thermal in the primary market area, while the remaining 3 percent cannot. The highest level of satisfaction of respondents is 61 percent, 37 percent of respondents are satisfied, and 2 percent of respondents are dissatisfied with the thermals of the leading market area.

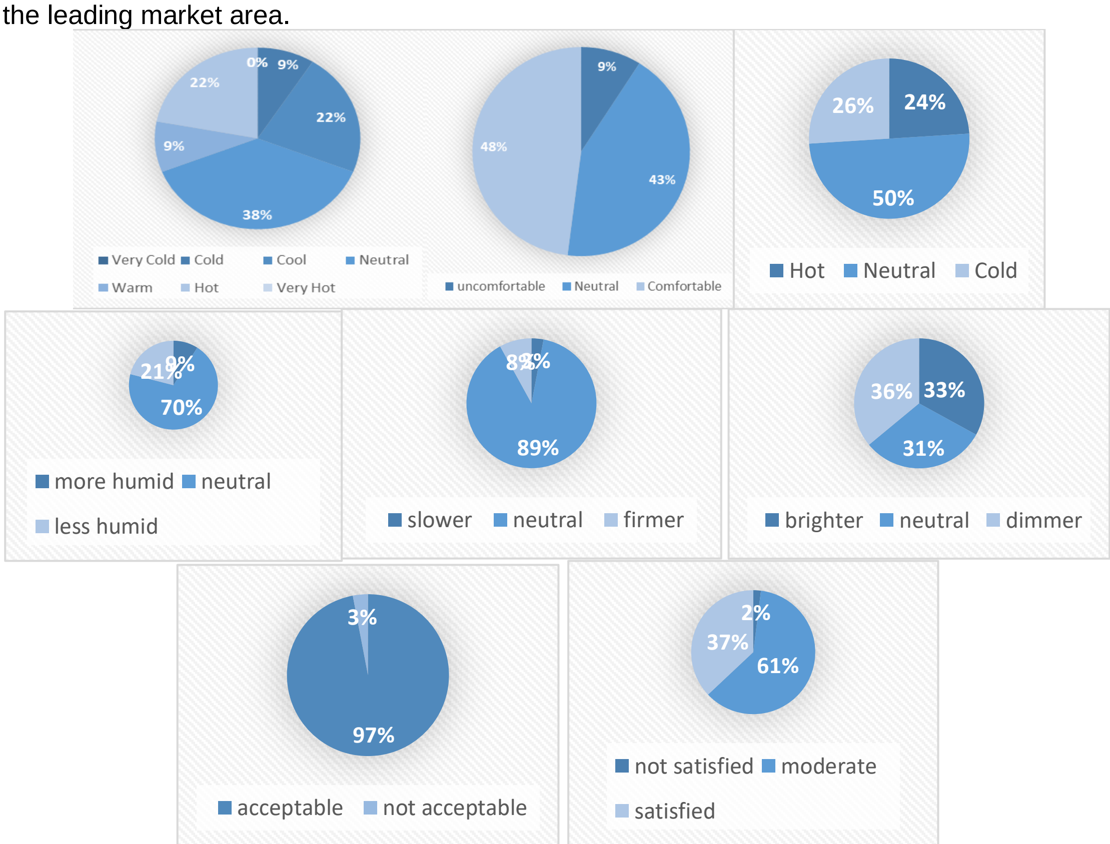

Figure 1: Thermal response, a. Thermal sensation, b. level of thermal comfort, c. comfort of air temperature, d. comfort of humidity, e. comfort of wind speed, f. comfort of sun intensity, g. thermal comfort of the environment, h. current thermal comfort.
Source: author, 2022

As many as 57 percent of respondents will wear a jacket when it is cold, 37 percent will drink warm water when they feel cold, and the remaining 6 percent will seek sunlight when they feel cold. When respondents feel hot, 61% of respondents will drink cold water to lower their body temperature, 31% will turn on the cooler, and 8 percent will use an umbrella.

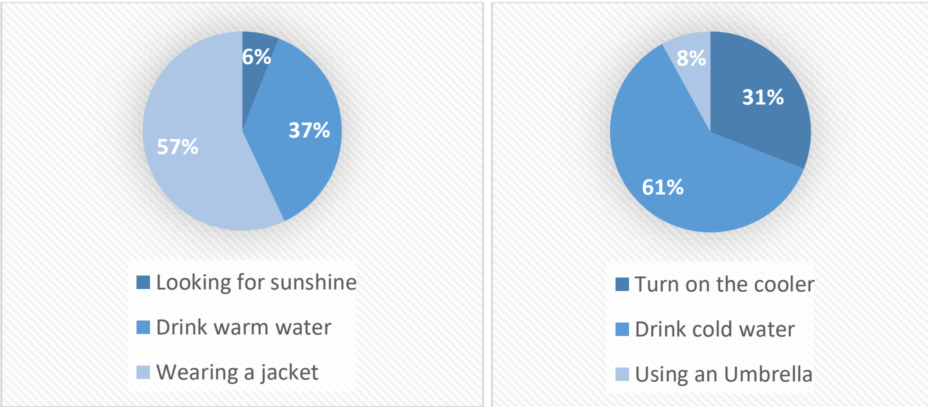

Figure 1: Thermal adaptation, a. activities carried out when it is cold, b. activities carried out in the heat
Source: author, 2022

Disscussion

Thermal conditions at the Wonosobo market show hot conditions in the morning, afternoon, and evening. The clothes of the Wonosobo people tend to use long sleeves of the culture that still prioritizes modesty, especially for women. Clothing is a factor that makes the thermal conditions hotter. Clothing is a factor influencing the thermal comfort felt by building users. Clothing has a value according to the type and thickness of the material. The choice of clothing for activities will affect the thermal comfort of the occupants, especially adaptive thermal comfort (Malik et al., 2020). Age, weight, and height are personal factors that affect thermal comfort. Variable differences will make differences in the thermal response of each individual. The age of each individual will affect the activities in the building. Adults or parents will do different activities with children in response to thermal. The behavior of different building users will make different responses to thermals (Um et al., 2022)

Building thermal conditions are based on user perceptions using a thermal sensation vote (TSV). The thermal sensation vote used can be detailed according to each variable used. TSV is a thermal perception variable that is used to find thermal perception based on international standards from ASHRAE (Feng et al., 2022). TSV has dependence on regional diversity factors such as climate, building typology, demographics, and culture. The diversity factor is often not considered an essential factor in national or international standards, thus limiting the feasibility of universal indoor environmental criteria. In addition, most standards provide recommendations for various categories of thermal comfort and air quality by focusing on the perception of the IEQ by occupants rather than productivity and health as quantitative criteria. The review shows that thermal comfort and air quality parameters are treated separately and without an integrated assessment of various dimensions related to environmental quality. Combining quantitative and qualitative methods will make the research more comprehensive (Khovalyg et al., 2020).

Conclusions

Thermal conditions in Wonosobo Market tend to heat up, making building occupants thermally uncomfortable. The standard of comfortable temperature in mountainous areas, which tends to be lower than in the lowlands, makes the Wonosobo market uncomfortable for building users. Qualitative data is obtained from a survey of respondents, which is currently a trend in qualitative research. The response of building users to thermals gets subjective results that can be used as the basis for improving building design. The embodiment of thermal comfort in the building will be by the wishes of building users by collecting subjective data from building users.

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