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Indoor Thermal Comfort Perception at Atrium Zone: Case Study of Naturally Ventilated Public Market

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ABSTRACT

Public markets are normally designed with passive design strategies such as natural ventilation and lighting. Besides, the atrium has become one of the architectural features to be designed in this building. The atrium attracts more visitors due to its spacious space. However, issues *with* inadequate ventilation, uncomfortable smell, overheating, and uneven daylight distribution might affect the condition of occupants in the zone. Therefore, this research is to study the thermal comfort perception of occupants in the public market, especially the traders, and investigate the indoor thermal comfort level for the atrium zone in the public market. Data was documented via the survey questionnaire and field measurement in the atrium environment. Two case studies were recognized as the main focuses namely Pasar Siti Khadijah (PSK) and Pekan Rabu (PR). The study was mainly conducted in the atrium zone of the building. The thermal comfort parameters such as air temperature, air velocity, and relative humidity were recorded, and the data were correlated to the result of the survey questionnaire. The results of the analysis show the traders felt slightly dissatisfied with the indoor air temperature and air velocity. The average air temperature of both atriums was not within the suggested comfort temperature by previous studies. A few suggestions have been highlighted to improve the thermal comfort of both atriums.

1. Introduction

The atrium is one of the most significant architectural features that can be found in commercial buildings. It offers numerous benefits such as daylight and socializing space. A commercial building like a public market act as a place for urban communities to get their daily needs and is often used for human activities. The development of people's economy is determined by how the public market plays the role in business growth. However, there are a few issues rose by researchers that happen in naturally ventilated markets. Inadequate natural ventilation factors make the market feel hot and airless and do not meet the provisions in air circulation planning [1]. Besides, insufficient air ventilation will take to an uncomfortable smell that comes from the selling goods and people. Overheating problems during hot days due to direct solar radiation from the top-lit atrium also

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become a common issue in the building [2]. Then, Samant stated uneven distribution of sunlight within the atrium adjoining spaces where sunlight varies significantly with every floor level [3,4]. As the public market brings together occupants from community members, local business traders, and visitors from a variety of demographic, indoor environment quality and thermal comfort need to take attention seriously.

In this research, there are two case studies to be focused on: Pasar Siti Khadijah, Kelantan, and Pekan Rabu, Kedah. These buildings have the same attributes: naturally ventilated buildings and atriums. Both public markets are famous destinations to be visited by local visitors and tourists. The scope of the study is limited to naturally ventilated public markets in hot and humid climates.

The research aims to investigate the perception of traders and visitors on thermal comfort quality at the naturally ventilated atrium in Pasar Siti Khadijah (PSK) and Pekan Rabu (PR). The objectives of the research are to (1) study the indoor thermal comfort level for the atrium zone in the public market (PSK & PK) and (2) investigate the thermal comfort perception of occupants in the public market (PSK &PK). Finally, significant research is to achieve a suitable design outcome for the atrium that meets the thermal comfort requirements of users of the public market.

2. Thermal Comfort in Atrium Space

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has stated thermal comfort as "that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation" [5]. Thermal comfort based on building science is also described as the balance of heat transfer between human and their environmental condition [6,7]. The main aspects affecting the human perception of thermal comfort could be classified into environmental and personal factors. D' Ambriosio *et al.,* [8] have defined the main four environmental parameters include air Temperature (T), Radiant Temperature (RT), air Velocity (V), and Relative Humidity (RH). Clothing insulation and Metabolic Heat are the personal parameters for thermal comfort.

Thermal comfort is needed in all indoor spaces in the building including the atrium area. Good ventilation strategies minimize energy consumption and improve productivity and work performance [27]. The development of atrium buildings is growing around the world. It has been recognized as one of the significant architectural features. Atrium design has been widely applied in commercial buildings worldwide to improve the aesthetics and use of natural daylight [9,10]. An atrium can create a space that facilitates circulation and socialization [11]. In a hot and humid climate, the atrium can be considered one of the purposeful openings for natural ventilation into a building. Designing atriums for hot and humid climates need significant and cautious attention to be reviewed to the different fragments of the atrium building design. In fact, integrating the atrium into the building can decrease energy consumption and enhance energy efficiency [12].

Atrium geometry design play's an important role in influencing daylight performance with respect to climate, the predictable level of thermal comfort, and the purpose and complexity of buildings. Moosavi *et al.,* [13] in their research has analyzed the four generic forms of the atrium; linear, semi-enclosed, attached, single-sided, and centralized.

Several in-depth studies have investigated the issues pertaining to the atrium design. Most of them stated excessive solar heat gain penetrates via the atrium during the day may lead to discomfort condition of the user in the area. Improving the building envelope is also expected to efficiently resolve other performance issues such as daylighting, indoor air quality, fire safety, and carbon footprints [26]. Poorly designed atrium has been found as the main problem of this issue. Considering the right atrium design will produce better thermal comfort for people. The findings show the series

of papers from Omrany *et al.,* [14], Mohammad Yusoff [15], *Yusoff et al.,* [16], Yunus *et al.,* [17], Ghasemi *et al.,* [10], Baharvand *et al.,* [18], Suhendri *et al.,* [19] and Hien *et al.,* [20] have discussed on atrium studies in a hot and humid climate. However, only Yusoff *et al.,* [16] have done studies on commercial typology which is the shopping mall.

An extensive literature review and analysis on thermal comfort in the atrium zone are conducted to gain an in-depth understanding of recent studies, particularly on issues, methodology, and building typology. Most of the studies have done hybrid methods including software simulation and field measurement to achieve accurate data collection and findings. According to studies, there lack field measurement and simulation assessment on commercial building typologies such as public markets, shopping malls, retail outlet malls, and so on. Most of the studies focus on office, institutional and hotel typology.

3. Methodology

This study utilizes survey and field measurement. The survey was conducted to derive the traders' perception and satisfaction with thermal comfort and the indoor thermal environment in the atrium area. The field measurement was performed synchronously with the questionnaire as a secondary method to support the data on indoor thermal comfort in the atrium as shown in **Figure 1**.

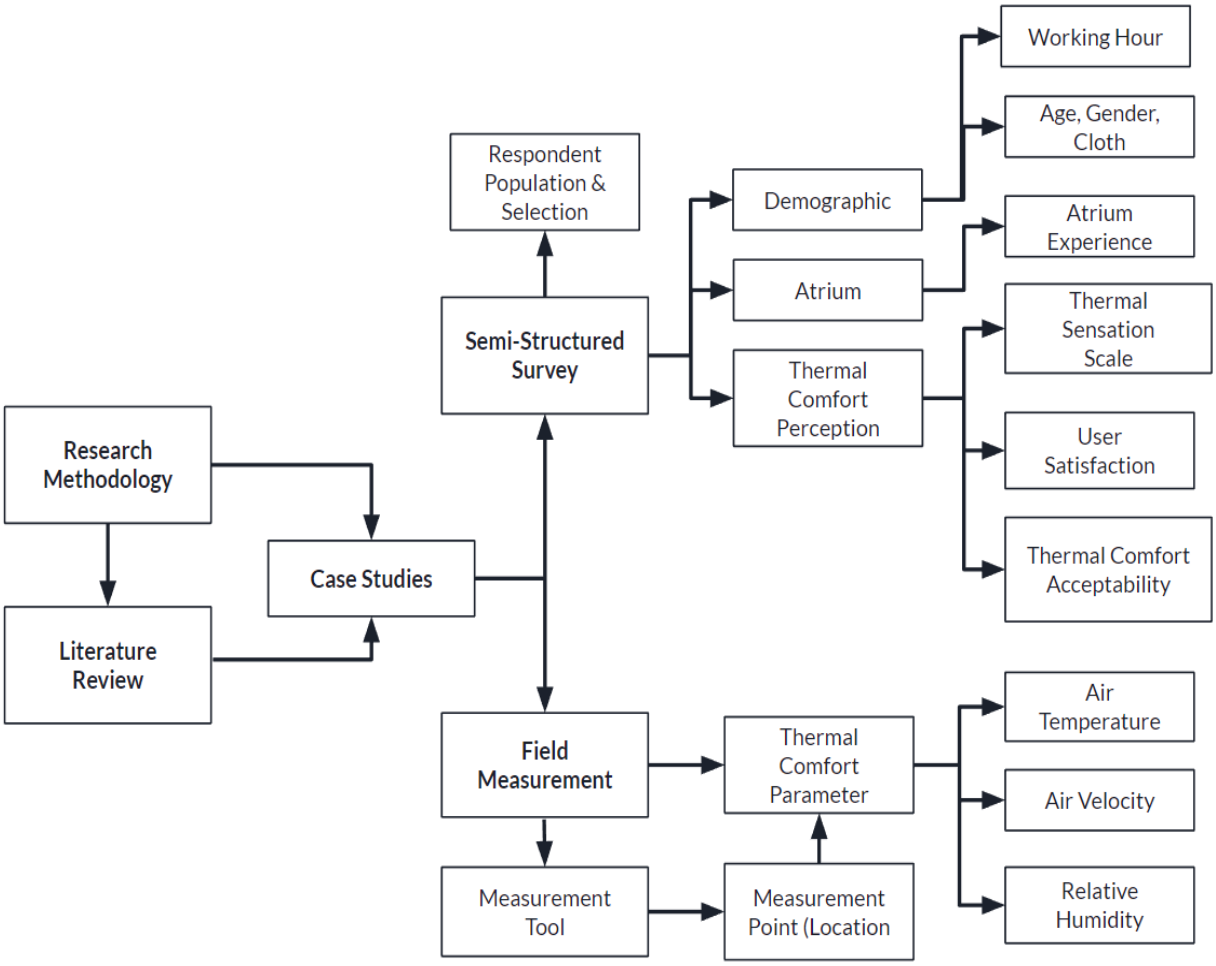
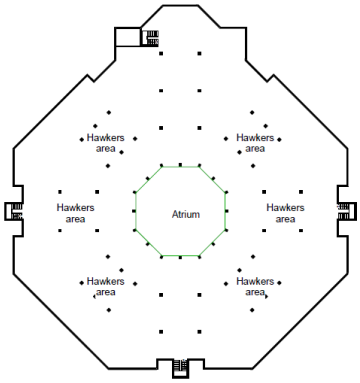
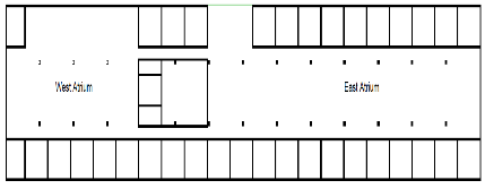


Fig. 1. Research framework.

3.1 Building Selection

Two public markets were identified as the case study for this research. These buildings have been categorized in commercial building typology. The two commercial buildings are named Pasar Siti Khadijah (PSK) and Pekan Rabu (PR). PSK is in Kota Bharu town, Kelantan meanwhile PR is situated in Alor Setar town, Kedah. Both buildings have shared the same attribute which is an atrium inside of the building. The atrium area in PSK and PR serves the purpose where the buying and selling activities become the main famous spot for buyers and tourists. Both atriums in the buildings (PSK & PR) are positioned on the ground floor level. In addition, the atriums' configurations of PSK and PR are classified as centralized forms. However, the roof configurations of the atriums are dissimilar between those buildings. Table 1 summarizes the physical criteria for both atrium zone.

Table 1
Pasar Siti Khatijah (PSK) and Pekan Rabu (PK) atrium physical criteria

CRITERIA	PSK	PK
Location	Ground Floor	Ground Floor
Study Area (m^2)	203	241 (East atrium)
Height (m)	17.3	13.2
Form	Centralized	Centralized
Layout Plan		

The atrium ground floor area at PSK has an area of 203 m^2. The space has 160 sales plots for traders to sell dry and wet goods. However, not all sales plots are occupied by the sellers during this research was carried out. Besides, the atrium has been surrounded by other stalls and sale plots on all four levels. The atrium has been connected via various passageways and corridors from the outside. As known as a naturally ventilated market, the airflow comes from outside openings via passageways. The atrium has a total height of 17.3 m from the ground level to the roof. The daylight penetrates the atrium area through the skylight as shown in Figure 2 (a). PSK atrium zone uses an exhaust fan on the roof area to increase ventilation.

The PR has two atriums that serve different functions, and the total area is 347 m^2. The west atrium has a total floor of 106 m^2 and functions as a food court area. Most of the space is occupied by tables and chairs. Meanwhile, sales booths in the east atrium occupy another 241 m^2 total floor area. The study concentrates on the east atrium due to most selling activities happening in this atrium. All the sales booths are selling dry goods such as apparel, fabric, watches, and dry food. During this study was carried out, there were 15 sales booths occupying the space. The height of both atriums is 13.2 m from the ground floor level. Contrary to the PSK's atrium, the natural lighting at the

roof level penetrates from the glass louvers located at the side wall. PK atrium uses a giant ceiling fan located at the roof beam in the center of the atrium as shown in Figure 2 (b).

(a) Pasar Siti Khatijah (PSK) (b) Pekan Rabu

Fig. 2. Top configuration of the atrium zone for (a) PSK and (b) PK public market

3.2 Questionnaire Survey

The study focuses on sellers as respondents who do selling activities in the atrium area (ground floor level) in both PSK and PR buildings. The questionnaire form had three sections. The first section emphasizes the respondents' demographic information such as gender, age, and attire. The second section focuses on basic information about atrium design. This section purposes to know how deep the respondents' knowledge of the atrium is. Meanwhile, the last section examines the thermal comfort perception of respondents in the atrium area. This section utilized ASHRAE thermal sensation scale (1: cold, 2: cool, 3: slightly cool, 4: neutral, 5: slightly warm, 6: warm, 7: hot) to examine respondents' thermal sensations [21]. Respondents' satisfaction with the atrium thermal environment has been evaluated with the 7-Likert scale (1: very dissatisfied, 2: dissatisfied, 3: slightly dissatisfied, 4: neutral, 5: slightly satisfied, 6: satisfied, 7: very satisfied). The population of the study was drawn from the sellers of PSK and PR. The total numbers of respondents for PSK and PR were 40 and 20 respectively.

3.3 Field Measurement

The field measurements at both PSK and PR atrium were carried out at different times due to separate locations. The measurement for the PSK's and PR's atriums was examined for 7 days in May 2022 respectively. The duration of field measurement was considered acceptable as these buildings are open 7 days a week. There were three main indoor environmental parameters recorded which

are air temperature (T), wind velocity (V), and relative humidity (RH). The indoor environmental data were documented at 15 minutes intervals. Then, the data were averaged to expound the average hourly However, the data was taken from 7 am to 7 pm and 9 am to 7 am for PSK and PR respectively due to different business hours.

The measurement tool utilized in the study was EXTECH EN300: 5-in-1 Environmental Meter. It has a measurement accuracy of ± 1.2 C for the air temperature, < 20m/s: ± 3% F.S. for air velocity, and < 70% RH: + 4% RH for the relative humidity. The tool was positioned 1 meter from the floor level during the field measurement. The placement of the tool is counted as acceptable for the sitting and standing positions. A few selected locations in the atriums (PSK and PR) were recognized in determining the data accuracy and safety issues of the tool as shown in **Figure 3** and **Figure 4**.

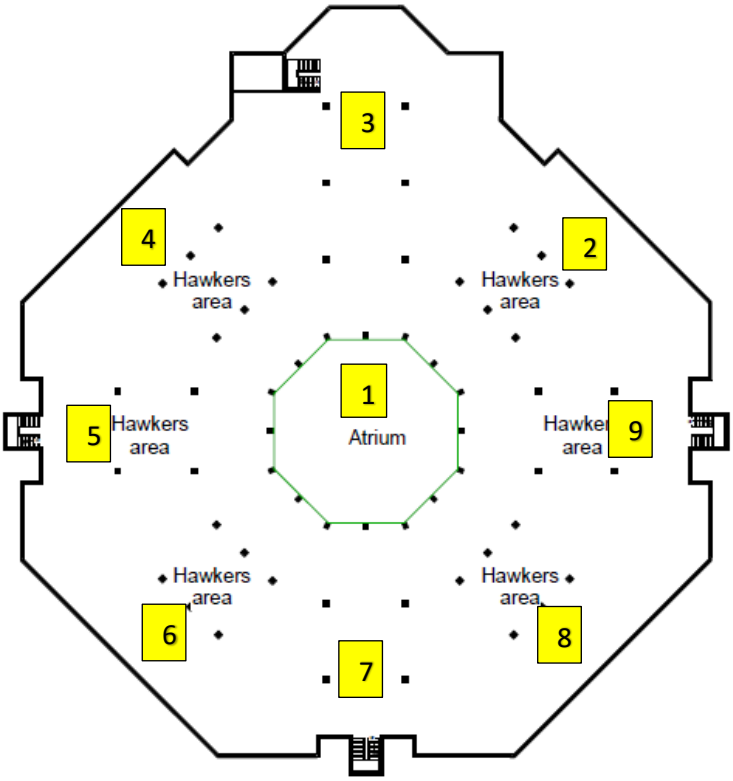


Fig. 3. Position of measurement in PSK atrium zone

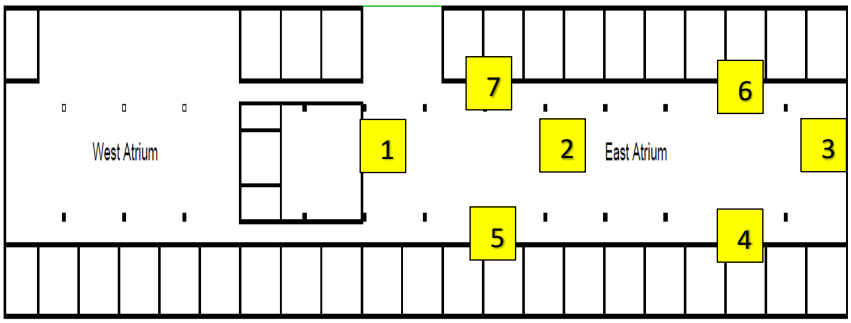


Fig. 4. Position of measurement in PR atrium zone

4. Result and Discussion

4.1 Personal Factor

The demographic information of respondents was obtained from the survey in PSK's and PR's atrium floor area. The findings show (Figure 5 and Figure 6) that the respondent's ages in PSK were mainly between 51-60 years old (40%) while the age between 41-50 years old took the second highest (27.5 %). Most of the respondents in PSK were female (87.5%). Meanwhile, the age range below 30 years old covered half the percentage of the respondents (50%) in PR. The data also indicates female respondents were dominant in the percentage (75%).

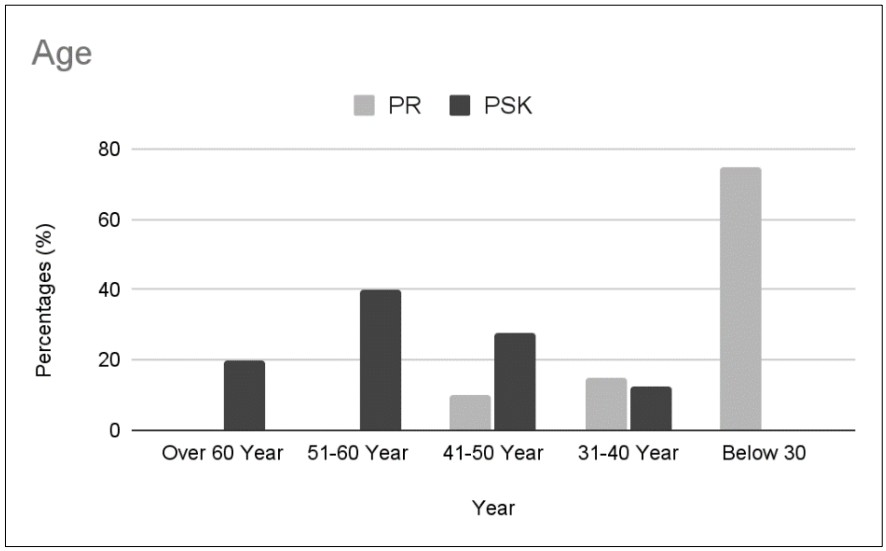


Fig. 5. Age of respondent at PSK and PR

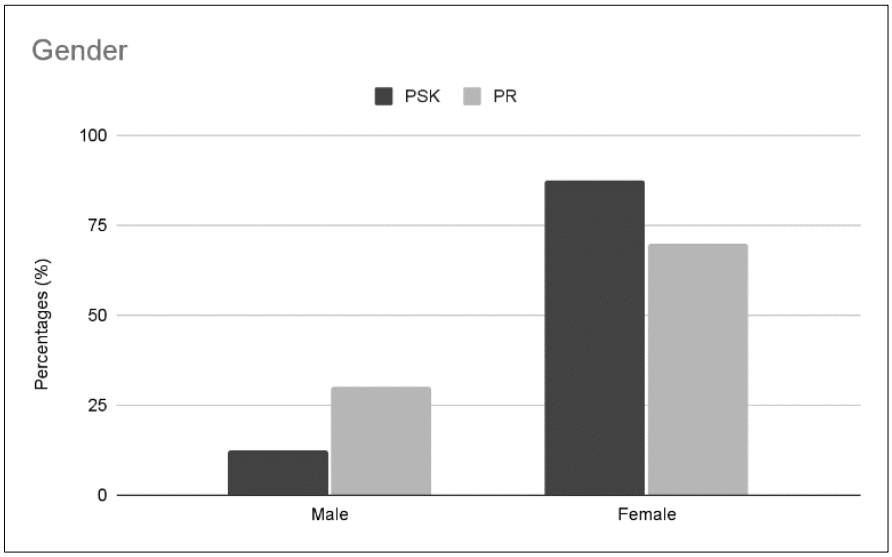


Fig. 6. Gander of respondents at PSK and PR

Most respondents have worked in PSK's atrium area for more than 10 years (85%) and the rest worked between 5 to 8 years (15%). In terms of years of working in PR's atrium, 85% of the respondents have worked 1-3 years and the others accounted for 15% who were below 1 year working year. Besides, all the respondents in PSK and PR work more than 8 hours a day in the atriums area (Figure 7 and Figure 8).

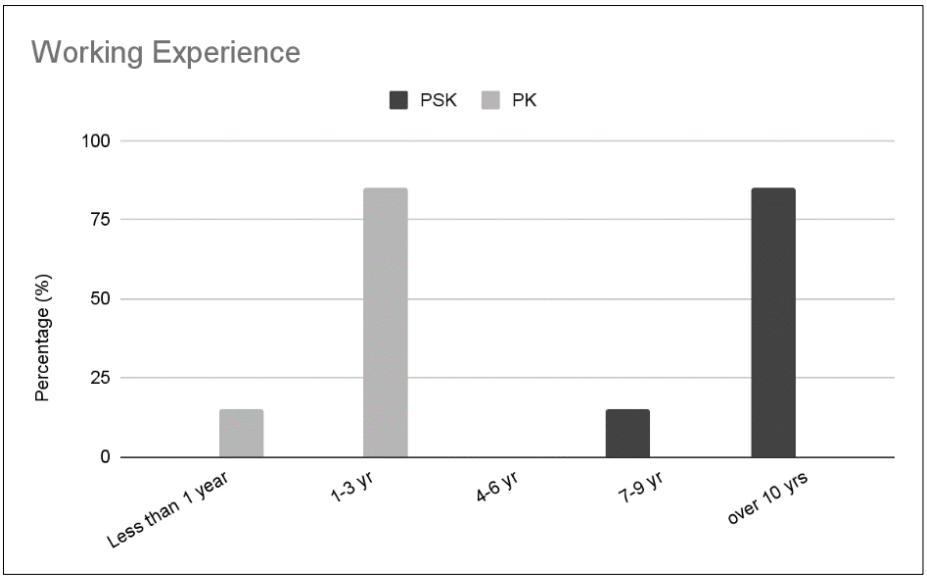


Fig. 7. Working experience of the respondents at PSK and PR

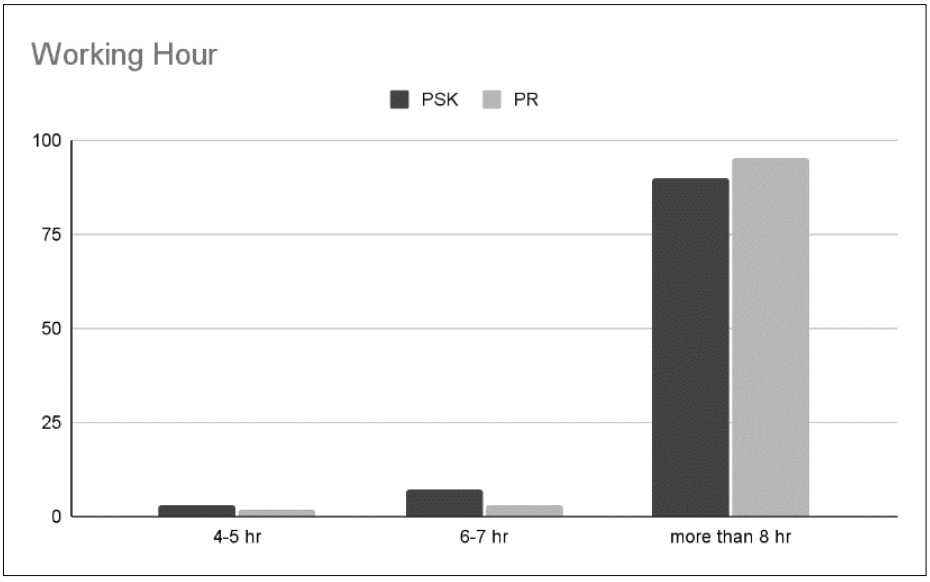


Fig. 8. Working hours of respondents at PSK and PR

4.2 Trader's Perception of Thermal Comfort

Traders or sellers in PSK's and PR's atrium area as the main respondent were studied to understand user perceptions and understanding of the indoor thermal comfort environment. In this section, the results are depicted via thermal sensation and satisfaction at the atriums of PSK and PR. Figure 9 indicates the traders' thermal sensation at the PSK's atrium. Most of the respondents felt slightly warm most of the time except from 7 am to 9 am and 6 pm and 7 pm. Other than being slightly warm, a few traders always felt neutral when working in the atrium area.

Figure 10 shows the thermal sensation of the respondents in PR's atrium. Throughout the measurement, the thermal sensation result indicates the traders felt neutral and slightly warm. Most traders or sellers felt hot from 12 pm to 2 pm.

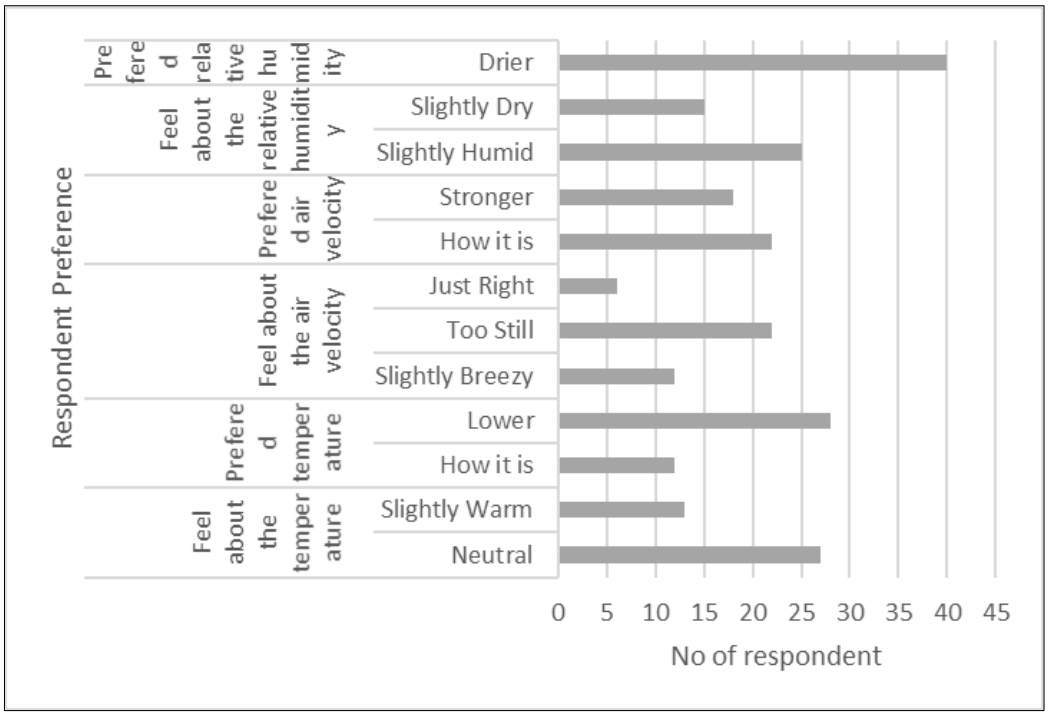


Fig. 9. Thermal sensation of traders in PSK's atrium

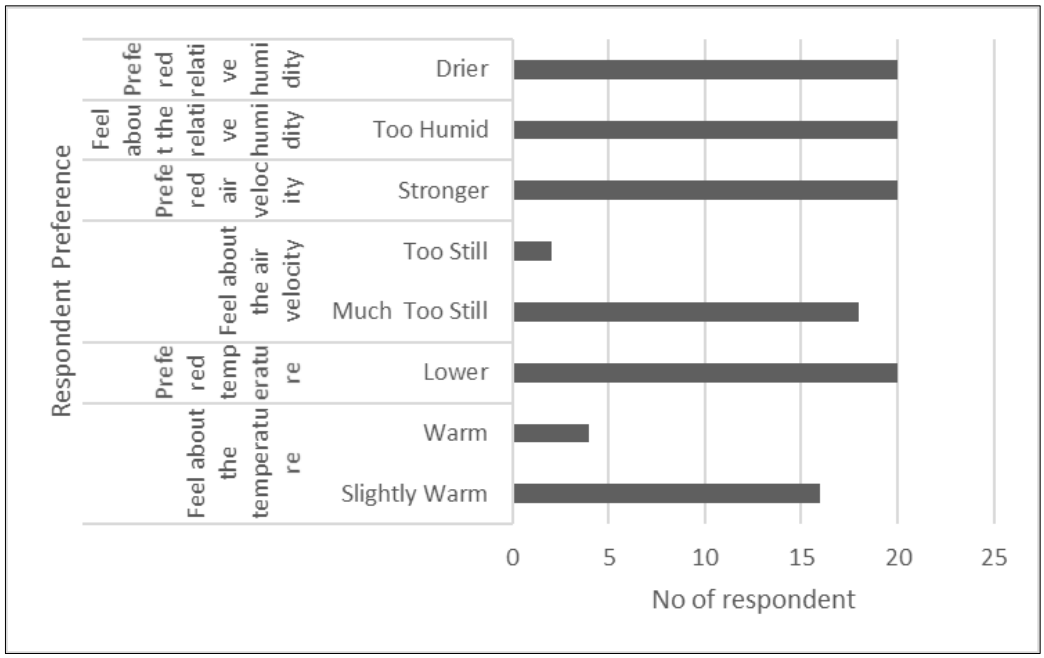


Fig. 10. Thermal sensation of traders in PR's atrium

The percentage of traders' satisfaction with indoor temperature in PSK demonstrates most of the time the traders felt neutral about it. It is found that 32.5% of respondents felt dissatisfied with indoor temperature. Hence, most of the time, the indoor temperature of PSK's atrium is acceptable to the traders as shown in Table 2. Dissimilar to respondents' satisfaction with the indoor temperature in PSK's atrium, the result of PR's atrium illustrates that 80% of respondents felt slightly dissatisfied with it. The rest of the respondents felt dissatisfied with the indoor temperature in PR's atrium.

Table 2
Indoor temperature acceptability

Time	Percentage of Acceptability (%)	
	PSK	PR
7 am	75	-
8 am	70	-
9 am	70	45
10 am	36	30
11 am	20	30
12 pm	20	15
1 pm	45	15
2 pm	45	10
3 pm	50	10
4 pm	52	10
5 pm	55	15
6 pm	58	15
7 pm	59	15

4.3 Indoor Environmental Data

The results in Figure 11 illustrate almost a parallel movement in both atriums. The air temperature rose from morning to afternoon and declined from afternoon to evening. The highest temperature can be seen during the afternoon. Nevertheless, the average indoor air temperature in PSK's atrium was observed higher compared to PR's atrium. The highest air temperature recorded in PSK's, and PR's atriums were 34.5 ^{o}C and 32 ^{o}C respectively at 1 pm (Table 3). Meanwhile, the lowest air temperature recorded in PSK's atrium is 27 ^{o}C at 7 am and it was a rainy day. PR's atrium has documented the lowest temperature reading of 30 ^{o}C. Table 4 indicates the average air temperature in PR's atrium based on point of measurement.

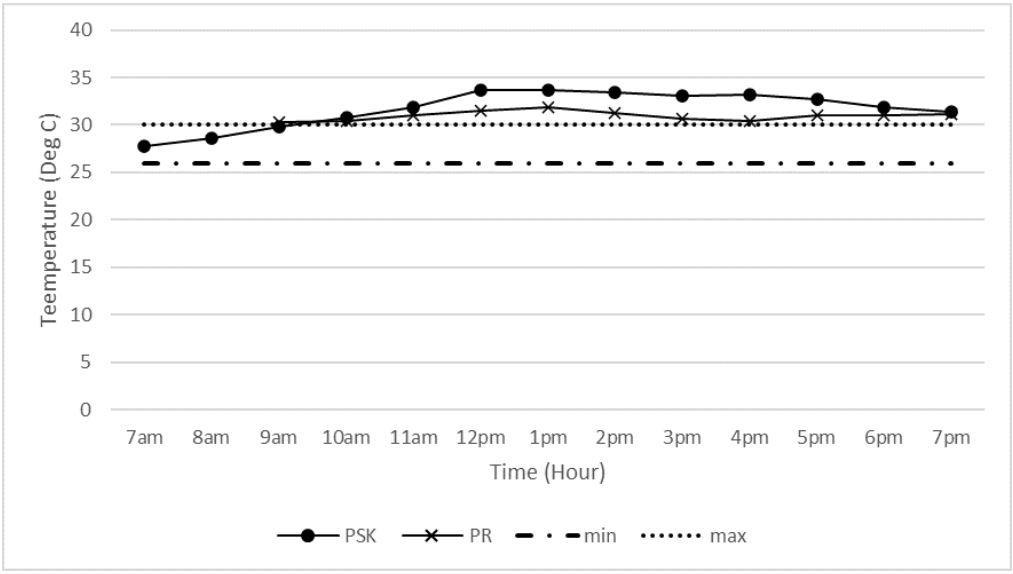


Fig. 11. Average indoor temperature of PSK and PR's atrium zone

Table 3
Average Air Temperature, T (deg C) in PSK's atrium zone based on point of measurement.

TIME	Average Air Temperature, T (deg C), and point of measurement								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
7 am	28	27	28.5	28	28.1	28	28.2	26	28
8 am	29	28	29	28	29	28	29	28	29
9 am	30	29.5	30.1	29	30	30.2	30	29	30.3
10 am	31	30	31	30	31	31	31	31	31
11 am	32	32	32.1	31	32.2	31	32.3	32	32
12 pm	34.5	34	34	33	34.5	32	34.5	32	34.5
1 pm	34	33	33	34	34	34	34	33	34
2 pm	33.8	32	33.8	33	33.8	33.3	34	33	33.8
3 pm	33.6	32	33.6	32	33.6	33	33.6	33	33.6
4 pm	33.4	32	33.4	33.4	33.4	33	33.4	33	33.4
5 pm	33	31	33	33	33	32.1	33	33	33
6 pm	32	31.1	32	32	32	32	32	32.1	32
7 pm	31	31	31	32	31	32	31	32	31

Table 4
Average Air Temperature, T (deg C) in PR's atrium zone based on point of measurement.

TIME	Average Air Temperature, T (deg C), and point of measurement						
	1	**2**	**3**	**4**	**5**	**6**	**7**
9 am	30	30.6	30.1	30.6	30.7	30.2	30
10 am	31	30	30	30	30.5	31	30.1
11 am	32	32	30.5	31	30.6	31	30
12 pm	32	32	32	32	31	31.1	30.1
1 pm	32	31.6	32	32	32	32	31.6
2 pm	31.6	31	31.6	31.6	31.3	31.1	31
3 pm	31	30	31	31	31	31	30
4 pm	30	32	30	30	30	30	31
5 pm	30.7	31	31.6	31.6	31.6	31	30
6 pm	30.6	31.1	32	31	31	31	30
7 pm	30	31	31	32	31	32	31

The indoor air velocity for the studied atriums is depicted in Figure 12. The average reading of indoor air velocity shown in PSK's atrium is 0.96 m/s (Table 5). The highest recorded reading is 1.66 m/s which is taken at the centre of the atrium. On the other hand, the data on average indoor air velocity in PR's atrium demonstrates lower reading compared to PSK's atrium which is 0.47 m/s (Table 6).

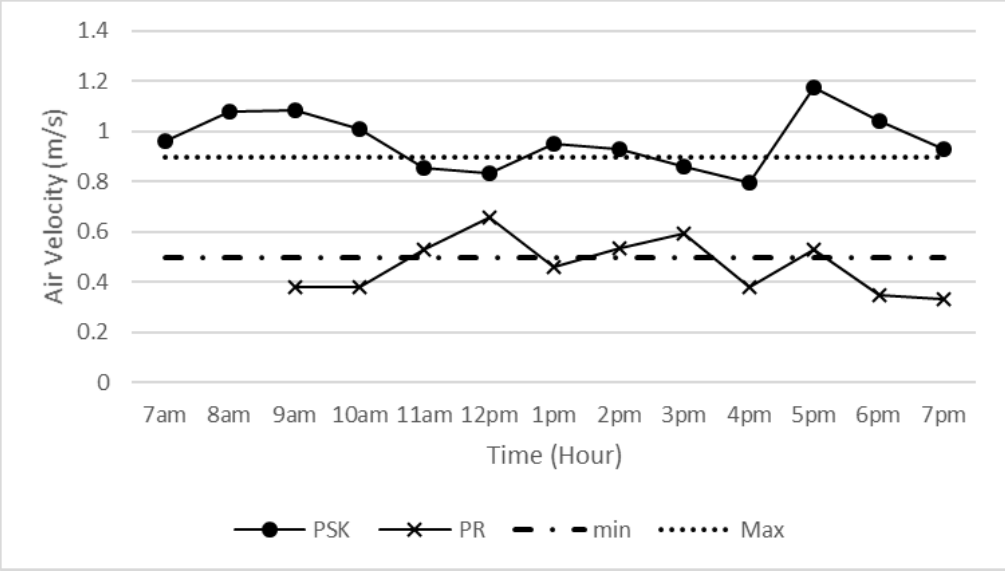


Fig. 12. Average air velocity of PSK and PR's atrium zone

Table 5
Average Air Velocity, V (m/s) in PSK's atrium zone based on point of measurement.

TIME	Average Air Velocity, V (m/s)								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
7 am	1.1	1.12	0.3	1.55	0.11	1.47	0.61	1.35	1.05
8 am	1.32	1.32	0.2	1.63	0	1.7	0.7	1.66	1.17
9 am	1.31	1.32	0	1.63	0	1.84	0.85	1.66	1.17
10 am	1.35	1.1	0.22	1.5	0.44	1.52	0.5	1.54	0.9
11 am	1.3	1	0.26	1.3	0.2	1.31	0.1	1.35	0.88
12 pm	1.3	0.99	0.1	1.33	0.1	1.33	0	1.33	1
1 pm	1.5	1.1	0.24	1.4	0.25	1.42	0.26	1.46	0.95
2 pm	1.44	1.11	0.23	1.46	0.33	1.46	0.2	1.46	0.7
3 pm	1.5	1.2	0.1	1.34	0.22	1.34	0.2	1.34	0.5
4 pm	1.3	1.27	0.3	1.2	0.28	1.23	0	1.27	0.3
5 pm	1.31	1.32	0.55	1.63	0.43	1.84	0.85	1.66	1
6 pm	1.11	1.28	0.2	1.55	0.1	1.84	0.7	1.5	1.1
7 pm	1.05	1.3	0.1	1.49	0.2	1.64	0.4	1.59	0.6

Table 6
Average Air Velocity, V (m/s) in PR's atrium zone based on point of measurement

TIME	Average Air Velocity, V (m/s)						
	1	**2**	**3**	**4**	**5**	**6**	**7**
9 am	1.31	0.05	1.2	0.05	0	0	0.05
10 am	1.2	0	1.35	0.03	0	0.05	0.03
11 am	1.3	0.05	1.3	0	0.05	0.99	0
12 pm	1.3	0.99	1.2	0.07	0.99	0	0.07
1 pm	1.5	0.07	1.5	0.04	0	0.05	0.05
2 pm	1.44	0.05	1.2	0	0.05	0.99	0.03
3 pm	1.5	0	1.5	0.05	0.99	0.07	0.05
4 pm	1.3	0.05	1.1	0.07	0.07	0.05	0.03
5 pm	1.31	0.95	1.31	0.05	0.05	0.03	0
6 pm	1.11	0.07	1.11	0	0.07	0	0.07
7 pm	1.05	0	1.05	0.05	0.05	0.07	0.04

The average indoor relative humidity of PSK's and PR's atrium is illustrated in Figure 13. The result shows the highest indoor relative humidity was recorded at 8 am in PSK's atrium (Table 7). At 9 am PR's atrium shows the highest reading of indoor relative humidity (Table 8). However, average indoor relative humidity on both atriums shows a slight difference where the reading shows PR's atrium is higher compared to PSK's atrium.

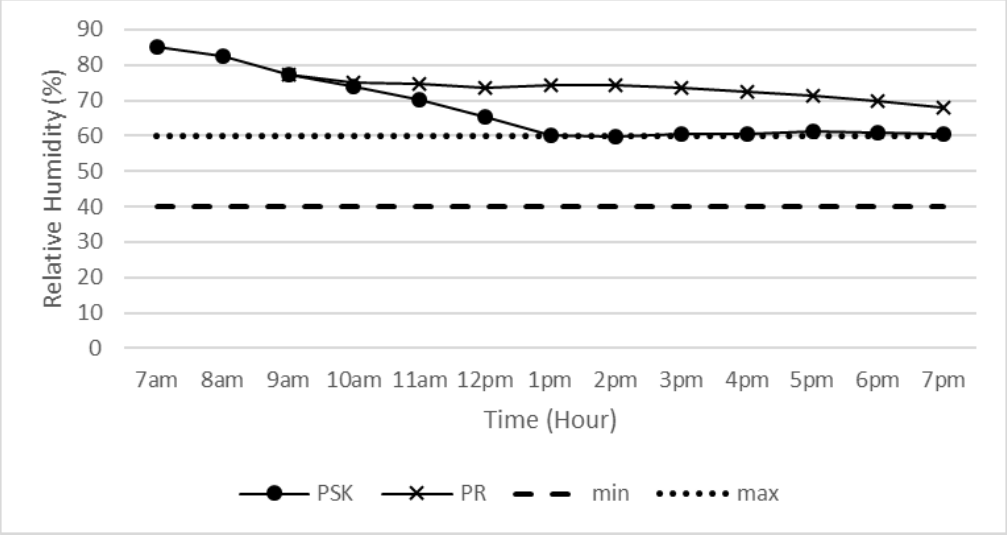


Fig. 13. Average relative humidity of PSK and PR's atrium zone

The results of the indoor environmental data of PSK's and PR's atriums present a similar outline of indoor air temperature. The indoor air temperature pattern starts to incline up from morning to afternoon and gradually declines towards the evening. The recorded reading of air temperature increases by more than 30 ^{o}C at 11 am in PSK's and PR's atriums. The traders in both atriums started to feel uncomfortable with the thermal sensation during that time until 3 pm. However, most traders in PR's atrium felt dissatisfied with the average air temperature though there was air velocity from mechanical means.

Table 7
Average Relative Humidity, RH (%) in PSK's atrium zone based on point of measurement

TIME	Average Relative Humidity, RH (%)								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
7 am	85	85	85	86	86	84	86	85	83
8 am	84	83	85	77.1	85	84	85	84	77.1
9 am	76	77.1	76	76	76	77.1	84	76	76
10 am	75	76	75	72	75	76	76	75	65
11 am	71	72	71	70	71.1	72	75	71	58.4
12 pm	65	66	65	69.1	65	66	67	65	60
1 pm	58.4	59.4	58.4	65	58.4	59.4	65	58.4	60.3
2 pm	59.9	60.9	58	58.4	60	60.9	58.4	60	60.1
3 pm	60.3	61.3	60.3	59.9	60.3	61.3	58	60.3	61.8
4 pm	60.1	61.1	60.1	60.3	60.1	61.1	60.3	60.1	60
5 pm	61.8	62.8	61.8	60.1	61.8	62.8	60.1	61.8	60
6 pm	60	61	60	61.8	60	61	61.8	60	61
7 pm	60	61	62	60	60	61	60	60	62

Table 8
Average Relative Humidity, RH (%) in PR's atrium zone based on point of measurement

TIME	Average Relative Humidity, RH (%)						
	1	**2**	**3**	**4**	**5**	**6**	**7**
9 am	76	77.1	76	76	76	77.1	84
10 am	75	76	75	72	75	76	76
11 am	75.3	73.2	75	72	75	76	76
12 pm	76.2	73	72	74	72.1	73	76
1 pm	75	75.3	73.2	75	74	74	74
2 pm	74.2	74.2	75.3	73.2	74.5	75	74.5
3 pm	73	73	74.2	72	74.2	73.2	74.2
4 pm	72	72	73	71	73	72	73
5 pm	71	71	72	70	72	71	72
6 pm	69	70	71	70	71	70	69
7 pm	70	65	70	68	70	66	67

Numerous previous studies had been carried out on indoor thermal comfort for naturally ventilated buildings, especially in hot and humid climates. Various methods were executed to suggest the appropriate temperature. Djamila *et al.,* [22] suggested the best temperature is 30.2 ^{o}C, Daghigh [23] proposed 26 ^{o}C to 28.9 ^{o}C, López-Pérez *et. al.,* [24] suggested 26.9 ^{o}C as an appropriate comfort temperature and Yusoff [15] recommended the temperature below 30 ^{o}C for finest indoor air temperature. Hence, it can be concluded the average temperature range of 26 ^{o}C to 30 ^{o}C is the perfect indoor thermal comfort temperature. However, both atriums in PSK and PK were not within the suggested thermal comfort range during the noon time. Nevertheless, there were traders who can accept the broader range of indoor temperatures. The study by Lau *et al.,* [25] shows that there some users in the naturally ventilated building can accept a wider range of comfortable indoor temperatures. Furthermore, their bodies can adapt to the temperature as they work for a long period

of time in that building. Besides, they can accept psychologically the temperature. Other than using the conventional air-conditioning system, the evaporative cooling system is more practical as the system uses relatively lower energy and is environmentally friendly by using water as a refrigerant [28].

The study reveals that the traders did a few actions to overcome the uncomfortable situations in the atriums as shown in Figure 14. The majority of them in PSK's atrium would use mechanical means such as fans to get more air movement and cool down their bodies. A few of them will change their clothing when they feel uncomfortable. Nevertheless, all the respondents in PR's atrium use mechanical means to cool down the air. Besides, they would move to comfortable places such as surau and food court to get fresh up themselves before continuing working. However, they did not change their clothing as they were comfortable with what are they wearing during the working day.

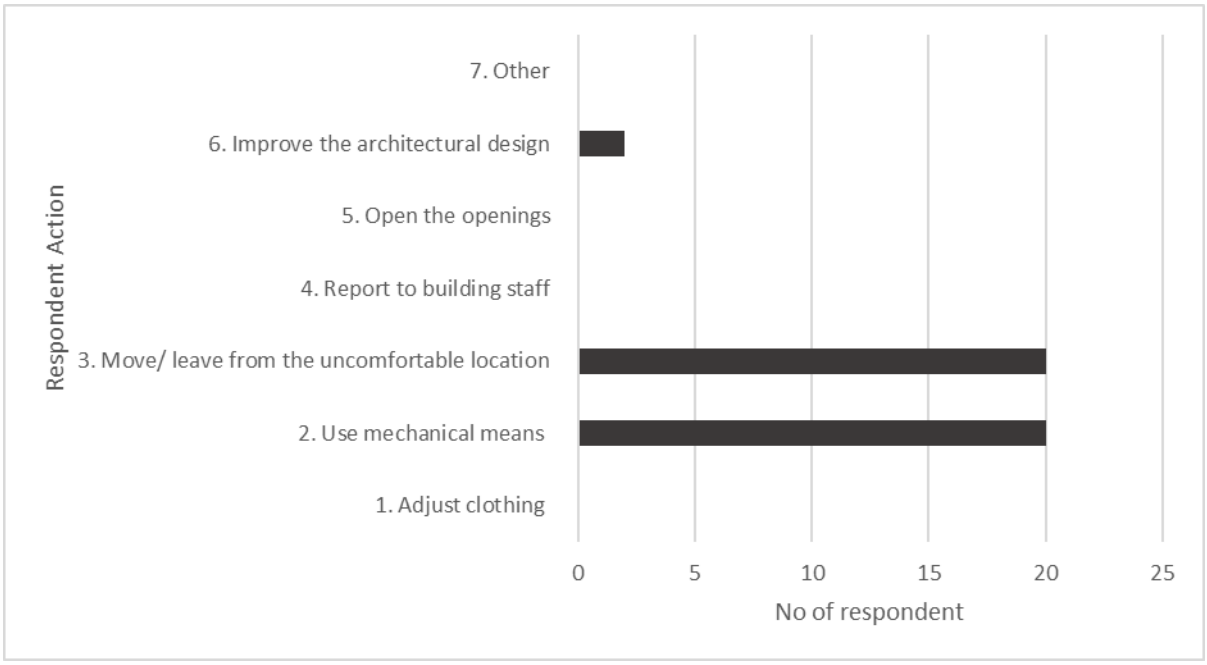


Fig. 14. Respondent action toward the uncomfortable condition on thermal comfort in PSK and PR atrium

5. Conclusion

This study was conducted to obtain the user perception of thermal comfort in ventilated public markets. The area of study focused on the atrium zone. The finding demonstrates a difference between Pasar Siti Khadijah (PSK) and Pekan Rabu (PR) in terms of air temperature, air velocity, and relative humidity. The thermal comfort parameters play important role in determining the trader's acceptability of thermal comfort. Besides, the top configuration of the centralized atrium approach is different between these buildings. The top of PSK's atrium is partially covered by opaque material to reduce the heat of sunlight, while the top of PR's atrium is a fully covered opaque ceiling. Both atriums are positioned in the center of the building and surrounded by other spaces. Thus, it will reduce natural ventilation to reach the atrium area and has lower air velocity. Both atriums have installed giant fans on top of the atrium. However, due to the ceiling being very high, the traders cannot feel the air velocity. This condition urges the traders to use other mechanical means to create more air velocity inside the area such as a stand fan. For the tropical climate, it is crucial to consider

the practical atrium design in a naturally ventilated market. More openings from outside should be well planned to allow more cross-ventilation inside the atrium area for the comfort of the traders. At the same time, solar heat penetration must be minimized without compromising the daylighting aspect. Thus, this is critical to understand the user perception of thermal comfort to produce the best atrium design, especially in the naturally ventilated market. Besides, a commercial place that seems to be uncomfortable may reduce the number of traders and sellers due to discomfort conditions. The atrium plays an important aspect in attracting people to visit the building because it creates a place to people gather and connect with each other. Future research should consider thermal comfort perception toward visitors of the public market in the atrium zone.

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