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Comparative Analysis of Thermal Conditions and Comfort Between Modern and Traditional Districts in Hot-Arid Climate: Case Study in Ajman-UAE

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ABSTRACT

Passive design solutions play a pivotal role in fostering sustainable practices within traditional architecture, as they empower historical urban designs to harmoniously engage with their surroundings and weather conditions, particularly in hot regions such as the United Arab Emirates. This research followed a qualitative approach to propose modifications for the thermal conditions and comfort in the modern contemporary urban districts based on the positive strategies from old traditional ones in a Hot-Arid Climate - Ajman-United Arab Emirates (UAE) as a case study using ENVI-met software-microscale three-dimensional software model for simulating complex urban environments. Moreover, this study made an evaluation and comparison of the outdoor air temperature and thermal comfort between the traditional and modern urban districts to highlight the passive design solutions that increase the thermal effectiveness in the traditional urban fabrics, as some of these passive design solutions can be used to modify the thermal conditions in the modern ones. Additionally, the research output revealed that the traditional urban design has valuable, sustainable strategies, as there was a decrease in the maximum reading for the air temperature for the traditional Ajman heritage district compared to the modern district on the 21st of August - as a reference day- and that improved the thermal comfort in the outdoor open spaces too. In conclusion, the study results confirmed that the thermal conditions in the existing modern districts could be improved using passive design solutions such as shading devices and greenery. Finally, this research is expected to be a phase amongst different phases that can benefit urban designers and architects to adopt strategies from traditional and vernacular urban projects and merge them with contemporary modern urban design.

1. INTRODUCTION

Sustainability holds significant importance in various facets of life, including the field of architecture. This is because architecture has the potential to produce eco-friendly structures that decrease energy usage and contribute to combating climate change [1, 2].

Contemporary architecture and urban design approaches are more directed toward forming regulations and use requirements rather than sustainability by considering the land use, the height of the buildings, built-up area to plot area, setbacks, etc., and that steered the current design strategies away from the traditional passive architecture and urban planning. Modern architecture and urban design indirectly participated in the cultural identity on the one hand. They increased the buildings' energy dissipation which accelerated climate change on the other hand. In contrast, the vernacular and traditional urban and architectural strategies reacted to the climatic and location circumstances and users' needs for local social and cultural ethics. Traditional design approaches are a valuable reference for creating sustainable designs [3-8] as they are good models for eco-friendly urban design. Traditional passive design approaches such as orientation, courtyards, shading devices, and vegetation were investigated and examined by many researchers to introduce new sustainable strategies for contemporary urban design and architecture, these approaches can be seen clearly in the traditional old heritage urban district in UAE as in Table 1.

Sholars like Salameh et al. pointed to the importance of the passive design solution that was dominant in the old traditional architecture and vernacular urban designs [3-5]. Drach and Karam-Filho [6] stated that these passive concepts facilitated the improvement of the thermal conditions for the interior spaces of traditional buildings with less energy consumption.

Moreover, researchers in the architectural and urban fields conducted different types of comparisons between traditional and modern urban fabrics, and most of them pointed to the better outdoor and indoor thermal performance for the traditional architecture and urban fabrics compared to the modern ones, as in Table 2.

Thus, there is high energy consumption in modern buildings and districts to improve thermal performance, especially in hot arid areas [9], for example, 70% of the total energy consumption in the UAE is used by buildings [10]. Afshari, Nikolopoulou, and Martin [11] added that Air conditioning systems in the UAE are responsible for about 57.5% of the electrical consumption for cooling the buildings. Katanbafnasab and Abu-Hijleh [12] insisted that consuming a lot of energy for cooling the buildings is a risky solution, as it aggravates climate change. While a better solution to design climate responsive architecture by Cantón et al. [13], like directing the design criteria to the proper passive design concepts rather than only modern fascinating architectural styles [14], which introduces glass facades with fewer shading devices that need a lot of chillers for cooling [15, 16].

Table 1. Traditional passive strategies in the Ajman heritage area

Traditional Passive Strategies	Images [17]	References Discussed These Approaches
1-Narrow pathways with a compacted plan for the urban tissue that provided shaded alleys. This urban design was a climate-responsive architecture that decreased the outdoor temperature between the buildings, thus creating better outdoor and indoor thermal environments.		[8]
2-Orientation and Small openings that reduced the heat transmission from outside to inside, which maintains more comfortable indoor spaces.		[18, 19]
3-Brajeel (wind catcher) as it is a traditional cooling system that allows air cold air to enter to replace the hot air inside the closed spaces inside the buildings.		[20, 21]
4-Courtyard as it uses the stack effect to replace the hot air (rises up) with cold air that cools down the building and supports the ventilation with a better air circulation system.		[22-24]

Table 2. Different studies compared the thermal performance of traditional and modern urban and architectural designs

Research	Location	Comparison Topic-Old and New Designs	Notes
[3]	Nablus -Palestine	Old and new buildings Nablus city - Palestine	The traditional building had less energy consumption for cooling and heating the inner spaces than the modern one.
[7]	North Egypt and Southern Portugal	Vernacular Mediterranean architecture	The passive design solutions of traditional architecture modify the inner thermal performance of the buildings compared to the modern ones.
[8]	Nablus -Palestine	Vernacular and contemporary urban districts	The properties of the traditional urban fabrics improved their thermal performance compared to the modern ones
[5]	Lar city-Iran	Traditional organic urban district and modern grid urban fabrics	Traditional urban fabrics provide better outdoor thermal conditions than the modern ones.

Therefore, this study emphasized designing an appropriate urban district with comfortable outside thermal conditions for the occupants in hot arid areas based on passive strategies for urban design. The urban passive design solutions used were extracted after a comparison between old traditional districts with contemporary ones to figure out some applicable traditional passive strategies in the old districts and integrate them into the contemporary urban district to improve its thermal performance. It is expected that these traditional approaches can reduce modern urban districts' hot temperatures and improve their thermal comfort.

2. MATERIALS AND METHODS

A quantitative research methodology was followed in this study for an analytical comparison and evaluation of the thermal conditions for case studies for a modern and a traditional urban district in the hot arid UAE. The comparison is conducted by ENVI-met software (Figure 1). The study was planned to point to constructive urban design strategies in traditional areas and then integrate them into modern urban areas.

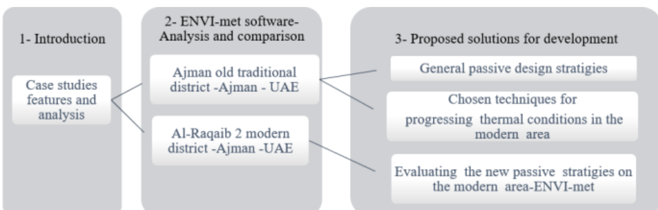
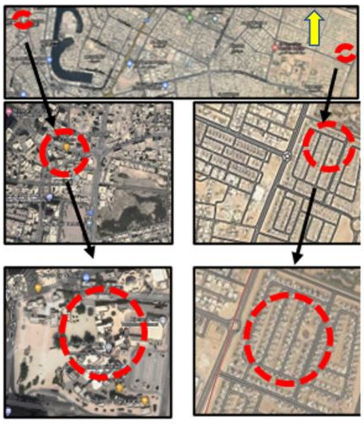


Figure 1. Outline of the research methodology

2.1 Case studies

The research investigations and thermal analysis were based on two case studies (Old and modern) in the hot arid UAE. Al-Raqaib-2 district-Sheikh Zayed Housing Program-Ajman was the contemporary new residential case study, while Ajman heritage district -Ajman was the traditional old residential case study with vernacular Architecture, as in Figure 2.



(a) Old case study- Ajman Heritage district (b) New case study Al Ragaib modern district (SZHP)

Figure 2. The old and new case studies for the research in UAE [25, 26]

2.1.1 First case: Al-Raqaib modern urban neighborhood

Al-Raqaib Housing Neighbourhoods in Ajman-UAE is the new contemporary residential case study, which was built by Sheikh Zayed Housing Program (SZHP) (Figure 3). This residential district site plan is composed of a vertical and horizontal grid pattern of streets and boulevards. Moreover, it consists of 306 two-story residential villas that are planned based on the municipality's modern measures with setbacks. This district included 11 outdoor social spaces around the private units to improve the gathering and the safe social interaction between the residents away from noise and danger of the car main circulation routes, particularly for youthful individuals. Some of the outdoor open spaces have widths that reach 15 m. This housing district design had a certificate of two pearls of Estidama- Abu Dhabi Urban Planning Council for satisfying the requirements of the Estidama board of sustainability for the design of housing units [27].

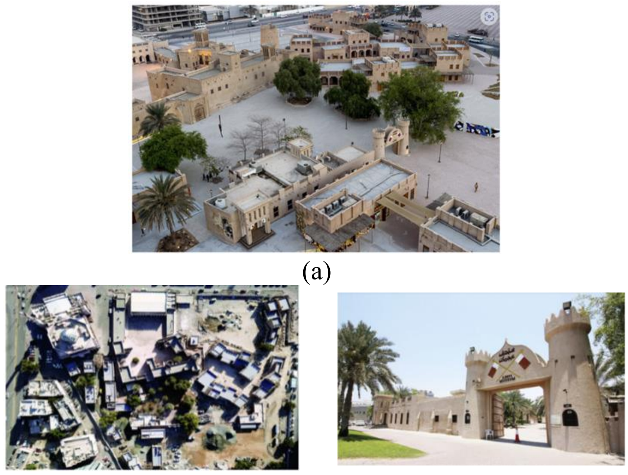
(a) Three dimensional image - Raqaib 2 housing project

(b) Top view - Raqaib 2 (c) Building units and outdoor spaces - Raqaib 2

Figure 3. Raqaib 2 - Sheikh Zayed Housing Program [28]

2.1.2 Second case: Ajman heritage district

Ajman heritage district in Ajman-UAE is the old traditional residential case study (Figure 4). This district is presumed to be the oldest area in Ajman city and was constructed in the 18th century as the first settlement of the emirates near the coast, Ajman Museum (fort) is assumed to be the main feature of the historic city, and it was the head of the emirate's dwelling until 1970. The district included many residential units. Some of them were demolished over time, and others are still standing today. This deep-rooted area in the hot arid climate of UAE has been, in the past, a sustainable, comfortable, and feasible environment for the inhabitants before the use of air conditioning. For many years Ajman municipality has implemented many efforts to rehabilitate and renovate this area as a live heritage example. This area is now used as an attractive tourism area, including Ajman Museum and exhibitions areas [29]. The heritage area in Ajman -like the other traditional areas in the UAE is famous for its passive design traditional strategies such as air pullers, rituals (arched pathways), Barjeels (wind catcher) beside the organic urban design layout.



(a)

(b) (c)

Figure 4. (a) Heritage area in Ajman [30]. (b) Top view for the heritage area in Ajman [31]. (c) Museum in heritage area [30]

2.2 Research software

Although there are numerous computer program bundles for displaying and examining the thermal conditions for urban microclimates, ENVI-met computer program is a pioneer in recreating the thermal conditions for urban design layouts because it is a 3D micrometeorological model [32]. Additionally, it is advanced in mimicking genuine microclimate conditions [33, 34]. This computer program incorporates high-resolution modeling for the precise microclimate conditions within the urban textures and around the constructions, based on fluid standards and atmospheric, physical, and barometrical measures, besides that it constrained real climate conditions [35]. Moreover, this software can calculate the outside climate conditions that include temperature, vegetation impact, stickiness, and water features [36]. In this research, different parameters were adopted for the thermal comparison between the old and new urban districts using ENVI-met, such as:

1-Airn temperature within the recreated microclimates for the existing urban setups of both the old and new urban areas.

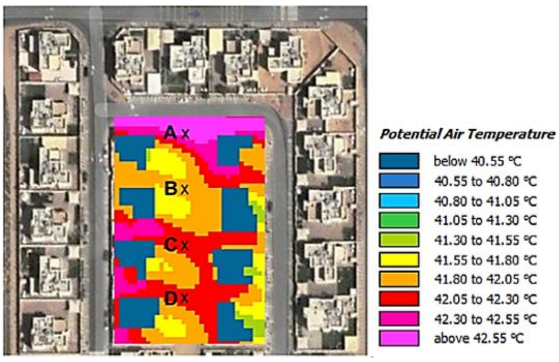
2-Levels for PMV (Predicted Mean Vote) for outdoor thermal comfort. PMV calculations are related to the energy balance of the users' bodies within the created microclimates. ENVI-met measures PMV based on the ASHRAE scale, where +3 is hot, and -3 is exceptionally cold [35]. And progressed it to be expanded scale for open-air ranges that extended between +4 being hot and -4 being cold [37].

2.3 ENVI-met software validation

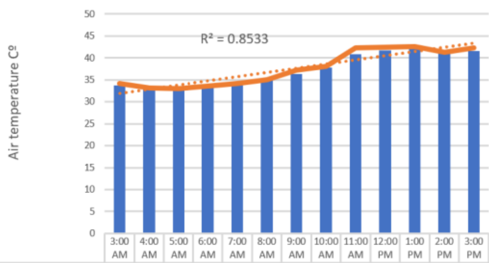
For software validation, Al-Raqaib's new district in Ajman was chosen (Figure 5(a)) for linking measured and simulated air temperature data. The simulation was conducted on the 21st of August, then 12 hours from the output simulation data for the air temperature were extracted from 3 am to 3 pm. Four points (A, B, C, D) were identified in the site to calculate the average air temperature at height 1.8 m for comparison with the measured data.

On the same date of simulation, field measurements were collected by using Extech 45170 meter at a level of 1.8 m on an hourly basis. The Extech meter has the following properties: it can measure the air temperature that ranges from 0 to 50℃, with a clear screen to show the measured data, it has ± 1.2℃ accuracy level [38]. Subsequently, a comparison between the air temperature from the field measurements and simulation data was conducted (Figure 5(b)). There was a good association with the two sets of data with R^2 of about 0.85 despite some variation, and that can be mostly explained with relation to the accuracy level of (Extech) meter for the field measurement.

Besides that, several studies confirmed the validity and the accuracy of the ENVI-met software for urban layout microclimate simulation such as References [39, 40].



(a) The four points in the modern residential urban fabric-Raqaib 2, that was used for validation



	3:00 AM	4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM
Av. simulated air temperature- ENVI-met	33.7	33.3	33.3	33.2	33.7	34.8	36.3	37.8	40.8	41.7	42	41.6	41.6
Measured air temperature- Field measurement	34.1	33.2	33	33.5	34.1	35	37.2	38.1	42.3	42.4	42.5	41.2	42.2

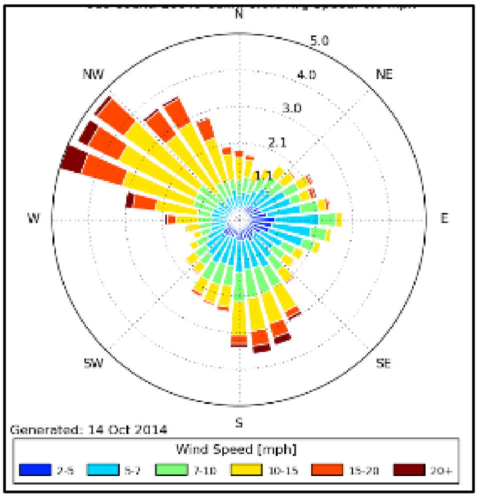
(b) Scatterplot for both sets data: Av. measured air temperature by Extech 45170 and Av. simulated air temperature by ENVI-met

Figure 5. Validation conditions and result for ENVI-met software output data in relation to field measurements data for air temperature on the modern district urban fabric-Raqaib 2

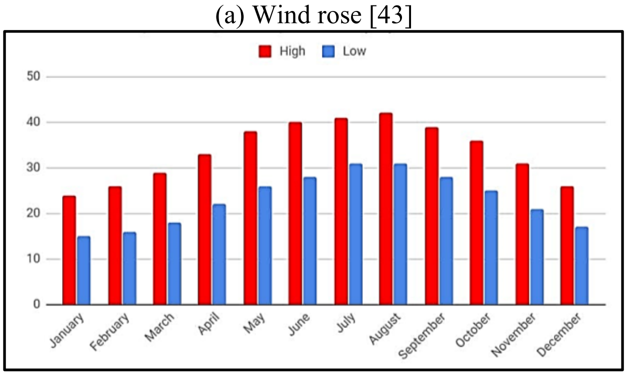
2.4 Case studies simulation dates and climate

This research focused on a comparative study between two traditional and modern districts in the hot arid climate of UAE in Ajman. UAE climate is known for its little rainfall and dominant northwest wind (Figure 6(a)), with 41℃ as the average maximum air temperature in August and 24℃ as the average minimum temperature in January (Figure 6(b)).

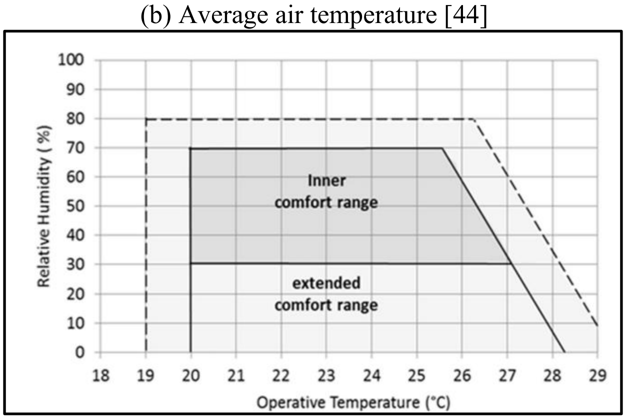
The research simulation and analysis considered the hottest month of the year in UAE which is August, as the air temperature is above the comfort level 27℃, based on Khalfan and Sharples [41], who stated that the comfort range is 20-27℃ according to Schnieders' thermal comfort diagram (Figure 6(c)). Accordingly, the air temperature and the thermal conditions were analyzed and compared between the two case studies, urban districts (old and new) on 21st of August, as the real challenge in hot areas like UAE is the reduction of electricity consumption for buildings' cooling [42].



(a) Wind rose [43]



(b) Average air temperature [44]



(c) Schnieders' thermal comfort diagram [41]

Figure 6. Case studies climate conditions in the UAE

2.5 Simulation and analysis conditions

For both case studies (old and new districts) a plot of about $160\times160m^2$ was defined for simulation and analysis (Table 3). The models in the ENVI-met software were created by using two units for dx=2, dy=2, and dz=2. The simulation was conducted for each model for 24 Hrs. on the 21st of August.

There were some shared fixed data for both urban fabrics of the case studies, including Building materials, location and climatic data. While there were independent features and data for each case study, such as: the urban layout, streets width, orientation and geometry, built-up area to plot area Proportion, Buildings heights, geometry and 3D forms, on the other hand, there were other dependent features - (Outcomes of the modelling) including the potential outdoor air temperature and the Predicted Mean Vote -PMV as in Table 4.

Table 3. Case studies urban characteristics

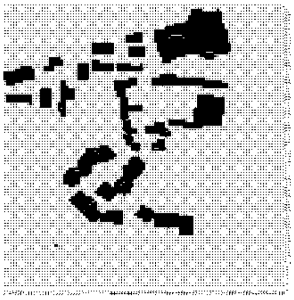
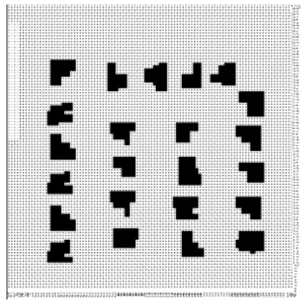
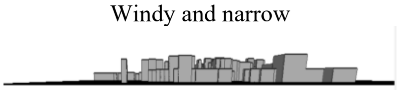
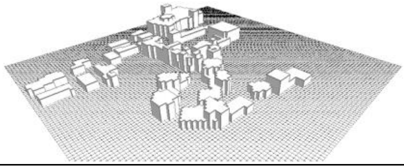
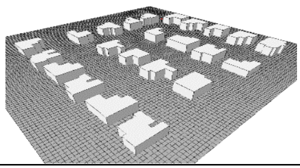
Case Studies Main Features	Ajman Heritage District	Al Ragaib Modern District - (SZHP)
District layout		
Plot area	Plot area=160×160=25600 m^2	Plot area=160×160=25600 m^2
built-up area		
Built-up area	Built up area around 11500 m^2	Built up area around 11500 m^2
Urban layout	Organic layout	Grid pattern layout
Streets width	Windy and narrow	Straight and Wide
Urban and street geometry		
Buildings height	One floor 4m, two floors 8m and wind catcher (Brajeel) 12m	Two floors 8m
Buildings type	Semi-attached houses	Residential-detached houses
3D geometry		

Table 4. Simulation criteria

Simulation Criteria	Contemporary and Traditional Areas
Shared data for case studies in the ENVI-met simulation	•Location - UAE •Climatic data: Hot and Arid •Building materials: 1-Brick road (red stones) for the sidewalks and pathways 2-Loamy soil for the unpaved spaces 3-Asphalt road for roads 4-Default concrete wall with moderate insulation for the walls and the roofs.
Each case study's Independent Features	•Urban layout •Built-up area to Plot Area Ratio •Street orientation and geometry and the width of streets •Buildings heights and geometry •3D forms for the case studies
Each case study's Dependent features - (Results of the simulation)	•Potential outdoor air temperature •Thermal comfort -PMV (Predicted Mean Vote)

3. RESULTS AND DISCUSSION

3.1 Thermal conditions comparison for the old and new districts

An area of 160m×160m from both case studies (contemporary and traditional) was modelled and simulated by ENVI-met software on the 21st of August. The simulation outputs revealed that there was a variation in the air temperature data between the traditional and modern case studies. The traditional case study - The Ajman heritage area, presented lower readings for the air temperature than the modern district, especially from 10 A.M. to 5 P.M. (Figure 7) in the time of peak hot hours. Mostly that was because of the nature of traditional area design, which has more compact layout, with narrower streets and semi-opened courtyards, which created additional shaded areas with lower readings for the air temperature than the modern district.

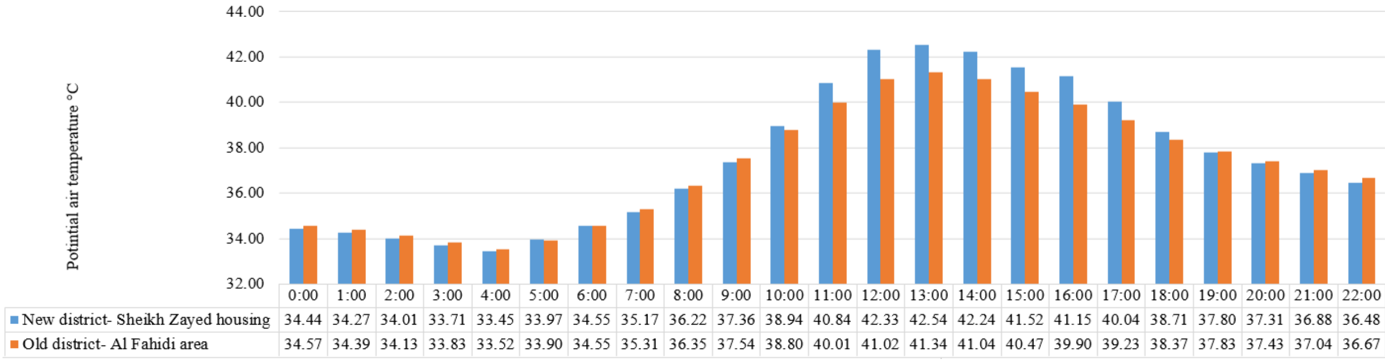


Figure 7. Average air temperature on the 21st of August

The hourly data for both cases presented more clear difference especially at 1 pm as one of the hottest hours of the day on 21st of August (Table 5), as in the modern district the minimum air temperature was 41.17°C and the maximum was around 43.90C°, while in the old district area the minimum air temperature was 40.15 and the maximum was around 42.5°C. Based on that the old district had a lower minimum air temperature of 0.49°C and a higher maximum air temperature of 1.35°C.

Table 5. Min, max and average air temperature on 21st of August

New District- Sheikh Zayed Housing	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Min	33.6	33.6	33.5	33.2	33.0	33.4	33.8	34.3	35.5	36.8	38.2	39.7	41.2
Max 1	35.3	34.9	34.6	34.2	33.9	34.5	35.3	36	36.9	37.9	39.7	42	43.5
Avg.	34.4	34.3	34	33.7	33.5	34	34.6	35.2	36.2	37.4	38.9	40.8	42.3
Old district- Ajman Heritage Area	**0:00**	**1:00**	**2:00**	**3:00**	**4:00**	**5:00**	**6:00**	**7:00**	**8:00**	**9:00**	**10:00**	**11:00**	**12:00**
Min	33.9	33.8	33.5	33.2	32.8	33.2	33.8	34.5	35.7	37.2	38.2	39.1	39.9
Max-2	35.2	35	34.8	34.5	34.2	34.6	35.3	36.1	37	37.9	39.4	40.9	42.1
Avg.	34.6	34.4	34.1	33.8	33.5	33.9	34.6	35.3	36.4	37.5	38.8	40	41

New District- Sheikh Zayed Housing	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00
Min	41.2	40.8	40	40.1	39.3	38.5	37.6	37.1	36.7	36.3
Max 1	43.9	43.7	43	42.2	40.8	39	38	37.5	37.1	36.7
Avg.	42.5	42.2	41.5	41.2	40	38.7	37.8	37.3	36.9	36.5
Old district- Ajman Heritage Area	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**
Min	40.2	40.1	39.8	39.5	38.9	38.2	37.7	37.3	36.9	36.4
Max-2	42.5	42	41.1	40.3	39.5	38.6	38	37.6	37.2	36.9
Avg.	41.3	41	40.5	39.9	39.2	38.4	37.8	37.4	37	36.7

The potential air temperature pattern distribution on the 21st of August at 1:00 pm and at a height of 1.8m is illustrated in Figure 8(a), where the type of the urban buildings' layout is shown for both case studies old and new. The ratio of the built-up area to the plot area is around 12000 m^2/25600 $m^{2,}$ which is about 46 % for both cases. The old heritage area had organic and semi-attached structures with relatively compacted built-up structures compared to the new one, as the new district had detached and totally separated buildings. The outline structure of the old district area produced additional shaded zones, which assisted in reducing the potential air temperature in it, opposing the new district, as the buildings were totally separated and distributed regularly according to grid structure and that reduced the number of shaded areas. In addition to that, the plan of the roads in the old district were sloped, irregular, and narrow between the buildings, which helped in amending the thermal settings by adding the shaded areas and reducing the solar gain, while in the new district, the streets were wide and straight, reaching to a width of around 15 m in some areas with less shaded zones.

Figure 8(b) demonstrates the histograms for the potential air temperature spreading fraction on the 21st of August at 1:00

pm at the height of 1.8 m for the old and the new districts. Figure 8(b) indicated that the histogram for the old quarter showed most of the high air temperatures were entered around 40.75°C, while in the new area, most of the high air temperature readings were centered around 42.75°C. The better air temperature in the old district can be explained due to the variation in the heights of the semi-attached organic buildings with heights from 4 to 12, besides the presence of the irregular pathways and courtyards, which increased the shaded areas and enhanced the air temperature, in contrast with the new district which had separated buildings according to grid pattern with fixed heights around 8 m, which decreased the shaded areas in the area.

PMV for the thermal comfort sensation was investigated for both old and new districts on the 21st of August at 1:00 pm, and the results were illustrated in Figure 9(a). It was clear that the range of PMV readings in the outdoor areas in the old district fluctuated between 6.12-7.69 on the PMV scale, and these readings were lower than the related readings in the new district, which had 6.37-9.01 PMV readings as in Figure 9(b). Regardless that both sites had PMV readings overhead the preferred levels of user satisfaction, the PMV settings in the old area were more favorable and arranged around 7.4, as they were lower than the related levels for the new district, which were arranged around 8.6 level.

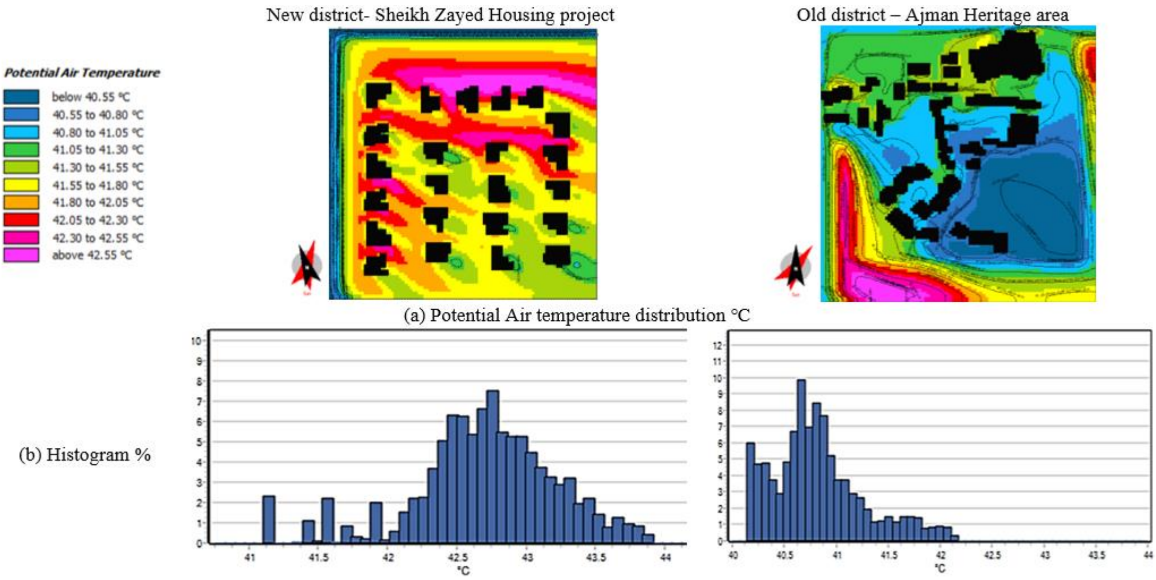


Figure 8. Distribution and histogram for the potential air temperature on the 21st of August at 1:00 P.M.

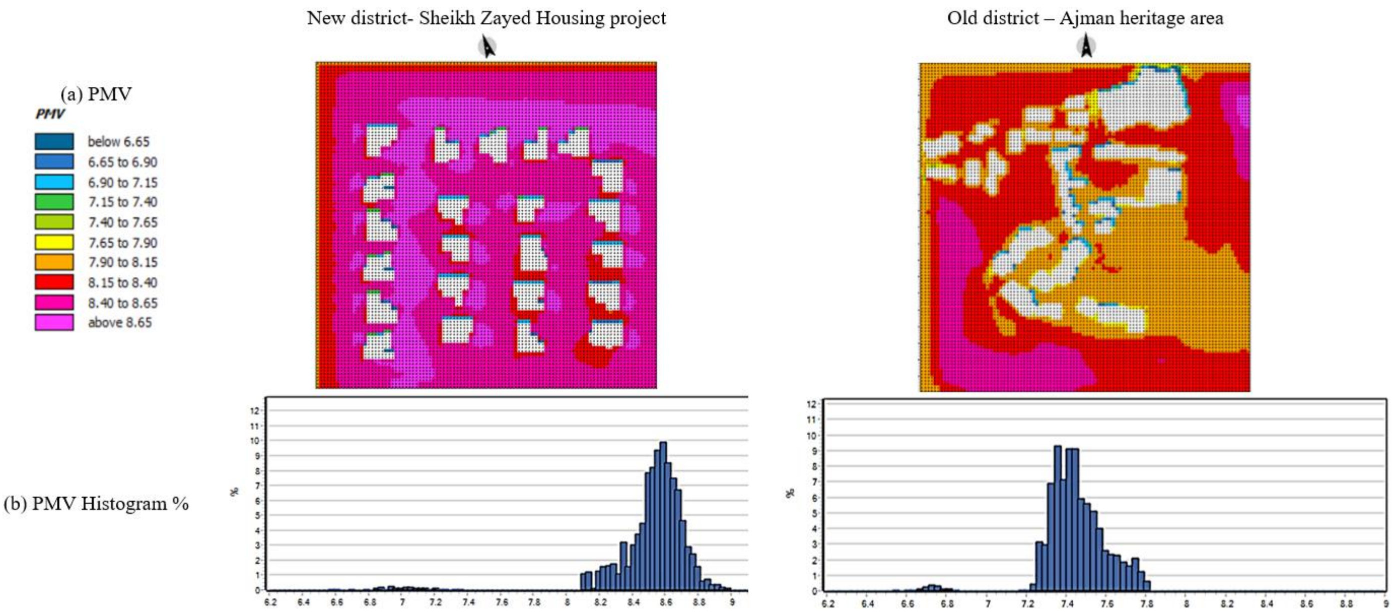


Figure 9. PMV readings and histogram for old and new districts on 21st of August at 1:00 P.M.

3.2 Proposals for enhancing the thermal settings in the new district- Sheikh Zayed Housing Project

The analysis in section 3.1 indicated better thermal environs in the old district - Ajman heritage area compared to the new district - Sheikh Zayed Housing Project in Ajman mainly due to the semi-connected irregular buildings' masses, narrow pathways and courtyard as traditional passive solutions that created more shaded areas. The shaded areas improved the air temperature in the outdoor spaces. Based on the analysis of the structure of the old district, there was a need to increase the shaded areas in the new district as one of the passive design solutions that can improve the thermal conditions. The main concern that these solutions should be to be integrated into an existing built-up neighborhood urban design to improve its sustainable approaches, thus, some issues need to be considered as the following:

1-It was not applicable to decrease the width of the pathways to create more shaded areas as the width of the streets was designed according to the municipality built-up regulations as the maximum width of streets and pedestrian reaches up to 15m.

2-It was not applicable to change the direction and the grid pattern from straight streets to windy streets to create more shaded areas in outdoor pathways.

3-It was not applicable to add more masses attached to the buildings to create compacted build-up areas following the traditional urban layout, as the new district' buildings were constructed based on setbacks according to the municipality regulation from all sides of each building's plot.

4-It was not applicable to add masses around the buildings to create courtyards or work on the orientation of the buildings as passive solutions because the buildings are already constructed.

Thus, it was clear that the proposed passive solutions for improving the urban thermal settings should be applicable to the constructed buildings and the general regulations for the urban layout without any manipulation in the building' masses, streets, or urban layout, for instance adding shading devices in front of buildings and in the open outdoor gathering area or adding green hedges to increase the shaded extents in the new district (Table 6) as the following:

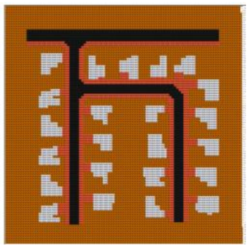
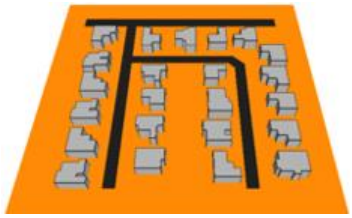
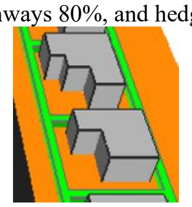
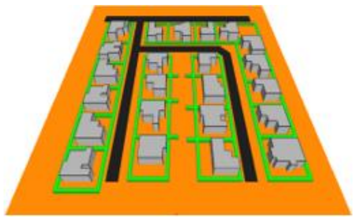
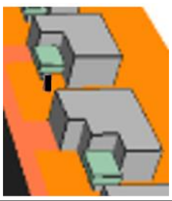
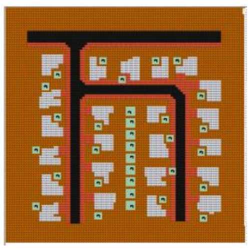
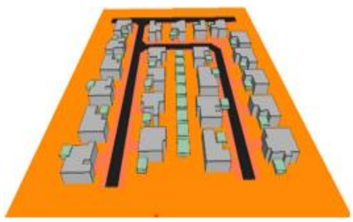
Solution 1: Hedges

By integrating green hedges, it is expected that more shaded extents with better thermal conditions will be produced in the modern district. Varshney and Mitra [45], Chen et al. [46], and Al-Kayiem et al. [47] highlighted the capability of hedges in refining urban thermal conditions and air quality. The hedges were proposed in the new district around the villa houses and in the middle gathering area of the district

Solution 2: Shading devices

By adding green shading devices in the new district, either next to the building or in the outdoor gathering area, it is expected that the thermal conditions for the urban area will be modified, as Bande et al. [48] stated that the integration of shading strategies in the open-air zones and streets can modify the thermal conditions in the urban districts in the arid hot areas.

Table 6. Proposed passive solutions for the new district

Cases	Specifications for Unbuilt Areas	Image	3D View
Base case for Sheikh Zayed Housing Project Loamy Soil Asphalt Road Brick Road (Red Stones) Concrete Pavement light Default Wall- Moderate Insulation	Brick road (red stones)- sidewalks and pathways 100%		
Solution -1: Hedges Loamy Soil Asphalt Road Brick Road (Red Stones) Concrete Pavement light Default Wall- Moderate Insulation Green Hedges	Brick road (red stones), sidewalks and pathways 80%, and hedges 20% 		
Solution -2: Green Shading Devices Loamy Soil Asphalt Road Brick Road (Red Stones) Concrete Pavement light Default Wall- Moderate Insulation Greenings with air gap	Brick road (red stones), sidewalks and pathways 90%, Green Shading devices 20 % 		

The two proposed solutions for modifying the outdoor thermal conditions in the new district urban fabric -Sheikh Zayed Housing, were simulated by ENVI-met software on the 21st of August. Referring to Figure 10 and Table 7, there was a variation in the average potential air temperature per hour between the base case and the proposed solutions.

In Figure 11(a), the differences in Max, Min, and average potential air temperature are clarified between the new district base case and the proposed two solutions on the 21st of August at 1:00 pm. For the new district base case, the maximum reading was 43.9°C, minimum 41.17°C, with an average of 42.54°C. The first solution, Hedges, had a maximum reading of 44.25°C, minimum of 41.08°C, with an average of 42.67°C. The second solution, Shading devices, had a maximum reading of 43.08°C, minimum 40.49°C, with an average of 41.8°C. Based on these readings, the second solution with shading devices showed better improved thermal conditions. The added shading devices in the new district succeeded in reducing the potential air temperature readings for the maximum by 0.82°C, minimum 0.68°C, and the average by 0.75°C. Although the reduction in the readings was not very high, they presented a good chance at improving the urban outdoor potential air temperature. The reduction in the Air temperature reduced the readings of the PMV mostly after integrating the shading solution, as this solution reduced the min PMV reading by 0.8 compared to the new district base case, as in Figure 11(b).

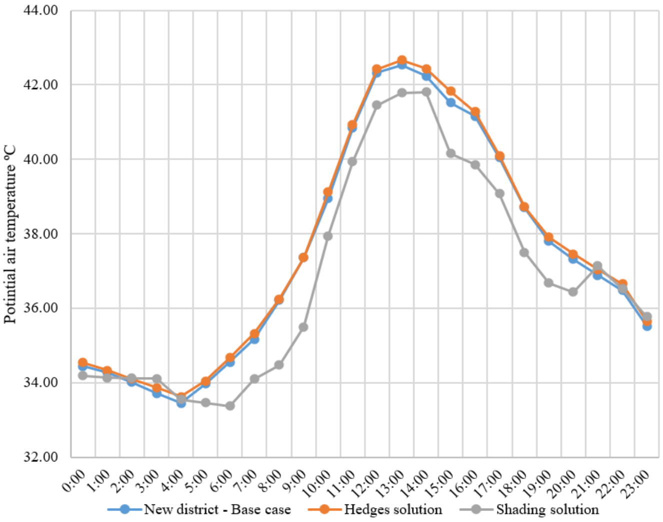
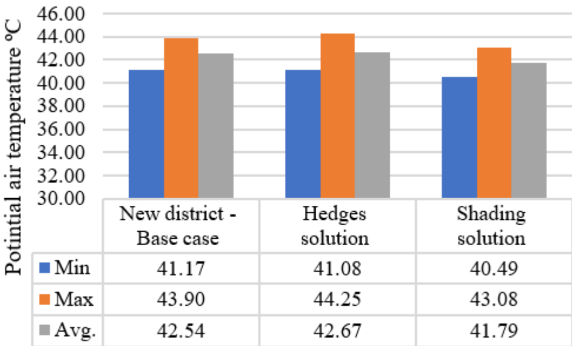
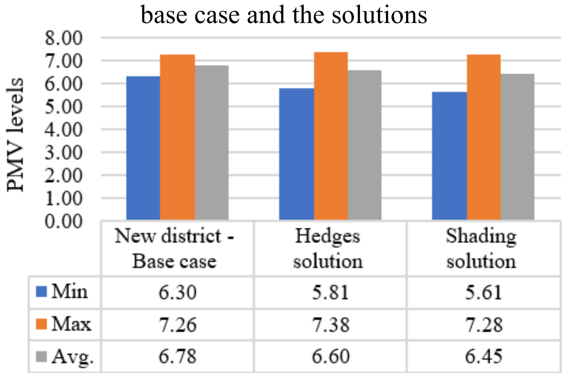


Figure 10. Average hourly potential air temperatures for the base case and the solutions at 13:00 pm on 21st of August



(a) Max, min and average potential air temperatures for the base case and the solutions



(b) Max, min and average PMV levels for the base case and the solutions

Figure 11. The max, min and average potential air temperatures and PMV levels for the base case -new district- Sheikh Zayed Housing Project- and the two proposed solutions on the 21st of August at 13:00 pm

Table 7. Av. potential air temperatures for the base case - new district- Sheikh Zayed Housing Project- and the two proposed solutions on 21st of August

	New District Base Case	Hedges Solution	Shading Solution
0:00	34.44	34.535	34.185
1:00	34.27	34.33	34.13
2:00	34.01	34.095	34.115
3:00	33.71	33.87	34.11
4:00	33.45	33.625	33.55
5:00	33.97	34.04	33.455
6:00	34.55	34.67	33.375
7:00	35.17	35.325	34.1
8:00	36.22	36.245	34.475
9:00	37.36	37.36	35.5
10:00	38.94	39.12	37.945
11:00	40.84	40.925	39.935
12:00	42.33	42.42	41.455
13:00	42.54	42.67	41.79
14:00	42.24	42.435	41.8
15:00	41.52	41.83	40.155
16:00	41.15	41.28	39.86
17:00	40.04	40.1	39.07
18:00	38.71	38.725	37.5
19:00	37.8	37.91	36.67
20:00	37.31	37.455	36.43
21:00	36.88	37.04	37.135
22:00	36.48	36.655	36.515
23:00	35.52	35.65	35.775

The improvement in the thermal behavior of the new district, which is linked to the integration of two proposed solutions (hedges and shading devices), is clearly illustrated in Figure 12. Figure 12(a) shows the potential air temperature distribution on the 21st of August at 1:00 pm, a time with high air temperature and solar radiation. The first solution, hedges, improved the area's overall thermal performance, but to a lesser extent than the second solution - shading devices. In comparison to the base case and the first solution, the shading devices in the second solution had the most effective distribution of air temperature. This resulted in a significant decrease in the potential air temperature in the southern west part from above 42.55 (purple color) to 41.55-41.80 (yellow color) due to the creation of shaded areas. The shading devices not only improved the thermal performance of the entire district but also enhanced the air circulation by creating variations in the air pressure. Beside that these shading devices has green roof thus it helps in decreasing the temperature by evaporative cooling. The shading devices succeeded in copying and mimicking the traditional old district by creating more shaded areas between the buildings and in the public open space.

Figure 12(b) confirmed the better positive effect of the second solution-green shading devices according to the differences in the histograms for the base case and the two solutions on the 21st of August. In the base case, most of the outdoor areas were 42.75ºC with a percentage of around 7.0% which was decreased to 5.5% in the first solution hedges and even reduced to around 5.0% in the second solution - green shading devices with air temperature readings that are more focused to lower levels, and that was as evidence for the improvement in the potential air temperature in the outdoor air temperature in the new urban district by the integration of the green shading devices, as it had better thermal performance than the first solution - hedges.

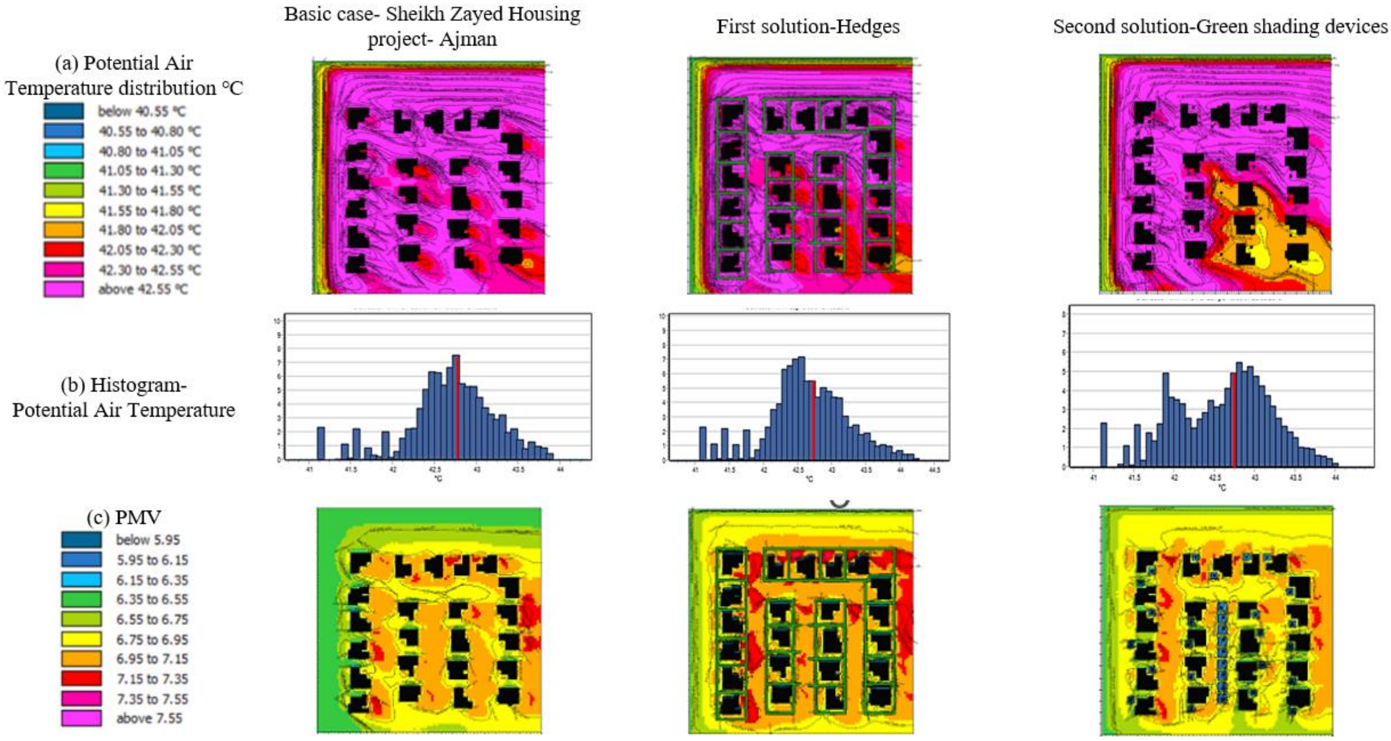


Figure 12. Potential air temperature and PMV for the basic case- new district and the proposed two solutions at 13:00 pm on 21st of August

Figure 12(c) shows the distribution for the Predicted mean vote - PMV on the 21st of August. The levels for the base case ranged between 6.30-7.26, and it was higher than the proposed solutions, as it ranged between 5.61-7.38 for the first solution- hedges and between 5.81-7.28 for the second case- green shading devices, and that presented a clear reduction in the PMV levels for the second solution by integrating - green shading devices. Regardless that the levels obtained by integrating the second solution- green shading devices were above the users' satisfaction levels, it succeeded in improving the general outdoor thermal comfort for the users.

4. CONCLUSION

The primary goal of this study is to mitigate climate change by reducing greenhouse gas emissions and creating healthy, comfortable urban areas with improved thermal conditions. Vernacular architecture and urban design were found to be valuable examples of sustainable architecture. In a comparative analysis between old and new districts in the hot, arid UAE region, it was evident that traditional urban fabrics performed better thermally due to passive design solutions like courtyards and compacted pattern orientation. Hourly data further highlighted the differences between the two districts, as in comparison to the modern district, the old district had lower minimum and maximum air temperature readings by approximately 0.49℃ and 1.35℃, respectively. As a result, the PMV readings in outdoor areas of the old district ranged from 6.12 to 7.69 on the PMV scale, which was lower than the corresponding readings in the new district, where the PMV scale ranged from 6.37 to 9.01. The study aimed to incorporate traditional passive design solutions into modern urban districts by increasing shading in outdoor areas. This was achieved by adding shading devices, resulting in a maximum reduction of 0.82℃ and a minimum reduction of 0.68℃ in potential air temperature readings. The average temperature was reduced by 0.75℃. Furthermore, the addition of shading devices led to a decrease in PMV readings by 0.67 for the maximum level and 0.33 for the average level, compared to the base case PMV readings. The research suggests that the reduction in outside temperature values positively affected the PMV readings in outdoor spaces. Consequently, the study recommends the integration of proper traditional passive design solutions as sustainable approaches in modern urban designs.

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