



مؤتمر عجمان  
الدولي السادس للبيئة  
Ajman 6<sup>th</sup> International  
Environment Conference



## Thermal Conditions and PMV Enhancements in Modern Urban Districts in relation to Traditional ones in Hot-Arid Climate – **Ajman-UAE as a case study**

**Dr. Muna Salameh**

–

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**AIEC2022**

Ajman 6<sup>th</sup> International Environment Conference on  
TOWARDS 2071 SHAPING THE FUTURE FOR ENVIRONMENTAL SUSTAINABILITY

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- Architecture is the main factor for producing a sustainable environment with reduced energy intake (Mumovic and Santamouris, 2018). (Fajer al Tawayha et al., 2019).
- The passive design concepts in the architecture were the basic component of the vernacular and traditional sustainable architecture (Biqaraz et al., 2019b).
- These concepts were incorporated in architecture to modify the thermal conditions with less energy consumption (Drach and Karam-Filho, 2014). (Fernandes *et al.*, 2014)



## 1. Literature review

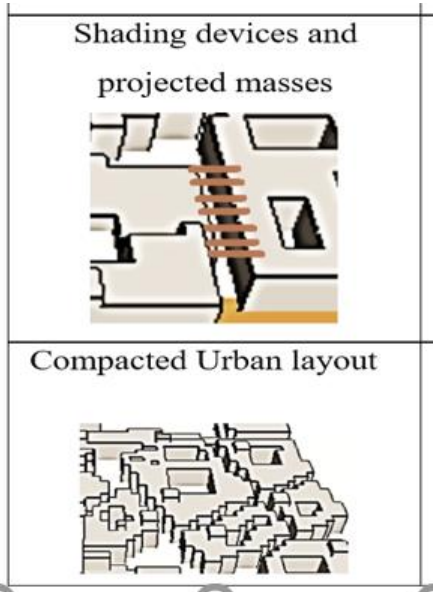
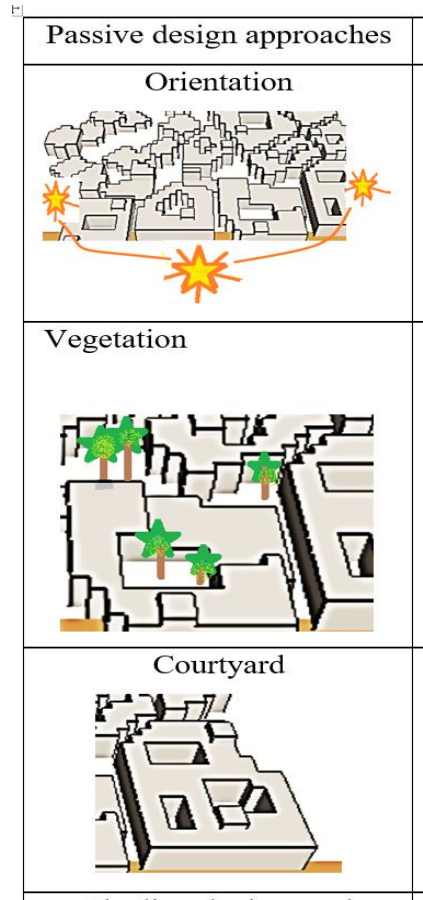
### - Modern and traditional urban design approaches

- **Contemporary architecture** and urban design approaches are more directed to forming regulations and use requirements rather than sustainability, by **considering the land use, 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 loss of cultural identity on one hand, and increased the buildings' energy dissipation which accelerated the climate change on the other hand.
- And that with contrast with the **vernacular and traditional urban and architecture** strategies, which were as reaction to the climatic and location circumstances and users' wants, and with respect to local social values and cultural.
- **Traditional design approaches are a valuable reference for creating sustainable designs**



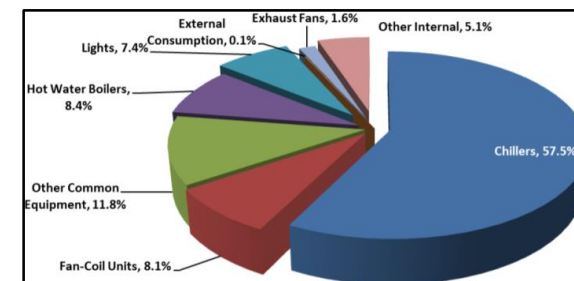
- Many studies and researches confirmed the **sustainable value of the traditional and vernacular architecture** after conducting a comparative analysis between a modern and traditional buildings or urban districts .
- The results confirmed that the traditional vernacular buildings and urban fabrics had better air temperature and thermal comfort than the contemporary and modern ones.

Reference –examples	Comparison topic - old and new designs
Biqaraz, Fayaz and Haghghaat Naeeni, 2019	Traditional organic urban district and modern grid urban fabrics in Lar city, Iran
(Al Tawayha, Bragança and Mateus, 2016	Vernacular and contemporary urban districts in the Mediterranean city of Nablus- Palestine
Fernandes <i>et al.</i> , 2014	Vernacular Mediterranean architecture in southern Portugal and north of Egypt
(Du, Bokel and van den Dobbelsteen, 2016	A Chinese modern and vernacular house
Salameh, et al. 2021	Old and new buildings in Nablus city – Palestine





- ❖ The demand for buildings and extended urban fabrics is increasing to handle the growing population; consequently, a vast amount of energy from fossil fuels is required for cooling these buildings (Hausladen, Liedl & De Saldanha 2012).
- ❖ For instance, cooling buildings (residential, public, services, and so on) consumes **around 70% of the energy in the UAE as a hot arid area**, (Perdikis 2015). And the chillers in the UAE consume around 57.5% of the total building energy consumption Afshari, Nikolopoulou, and Martin (2014)
- ❖ Thus the dependence on fossil fuel to maintain the luxury lifestyle was not a clever practical solution, as the high energy consumption required for buildings increases the CO<sub>2</sub> emissions and accelerates climate change (Katanbafnasab and Abu-Hijleh 2013).
- ❖ **Based on that buildings' designs and concepts should be developed to respond to the location and climate conditions of a given structure** Cantón et al. (2014).
- ❖ **In the case of the UAE**, architects have focused on imported designs with specific functions, forms or modern style more than designs that can cope with the harsh desert conditions (Clair 2009).

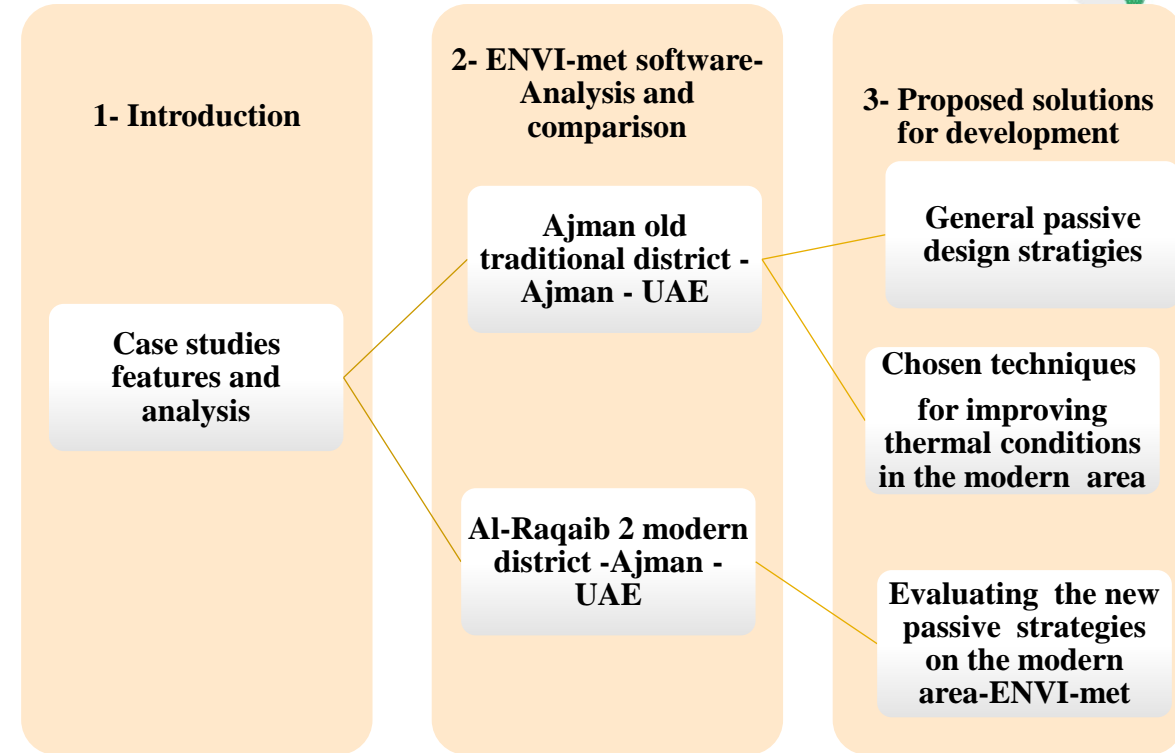




## Outline for the research methodology

### 2- Research aim and Methodology

- This research aimed to conduct a **comparison and evaluation for the outdoor thermal conditions for two case studies**
- A quantitative research methodology was followed in this study **by ENVI-met software** .
- The study was planned to point to the constructive urban design strategies in the traditional areas and then to integrate them in the modern urban areas to improve their thermal conditions.







## A-Case studies

- The research investigations and thermal analysis were based on two case studies (Old and modern) in the hot arid UAE that have the same built up area to plot area ratio which was about 44-45% for both case studies :
- **Al-Raqaiib-2 district** - Sheikh Zayed Housing Program- Ajman was the contemporary new residential case study,
- while **Ajman heritage district** was the traditional old residential case study with vernacular Architecture.



a- UAE map (Maps of UAE, 2021)



b- the traditional case study – Ajman heritage district (Ajman Heritage district, 2022)

c- Al-Raqaiib 2 modern district Ajman UAE- (Ajman, 2021)



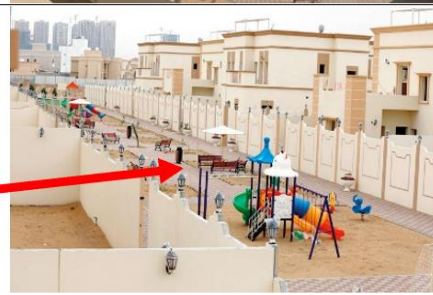
## Case studies for the research



a-Three-dimensional image - Raqaib 2 housing project (iskanZayed, 2021)



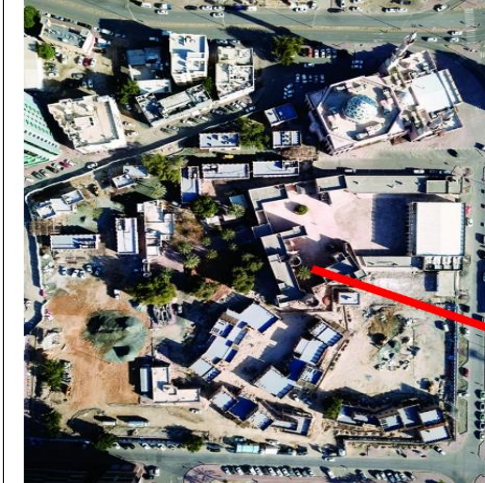
b-Site plan - Raqaib 2 housing project (Al Raqaib housing map, 2021)



c-Buildings units and outdoor spaces - Raqaib 2 housing project (Al Raqaib housing, 2021)



a- Heritage area in Ajman (Ajman heritage, 2022)



Top view for the heritage area (Ajman Heritage Development, 2022)



c-Ajman museum ((Ajman heritage, 2022)

**Al-Raqaib-2 district** - Sheikh Zayed Housing Program-  
Ajman was the contemporary new residential case study,

**Ajman heritage district** -Ajman was the traditional  
old residential case study with vernacular Architecture.



**The heritage area in Ajman** like the other traditional areas in the UAE, is famous for its passive design traditional strategies such as: riwaqs (arched pathways), Barjeels (wind towers) beside the organic urban design layout.

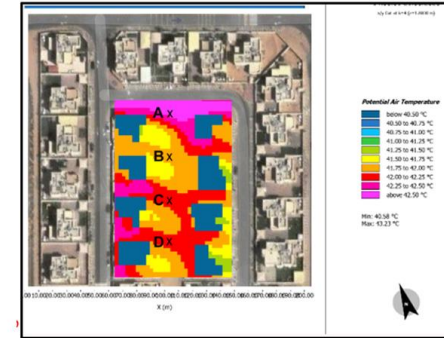




## B- Research software

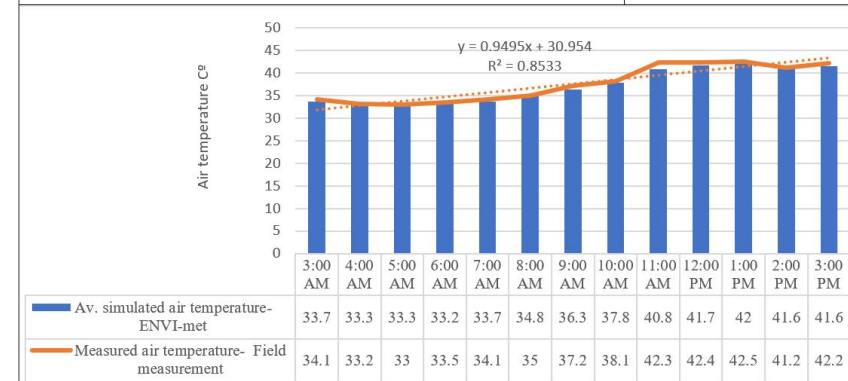
In this research different parameters were adopted for the thermal comparison between the old and new urban districts using **ENVI-met** such as:

- 1- **Potential air 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 is related to the energy balance of the users' bodies within the created microclimates based on the ASHRAE scale

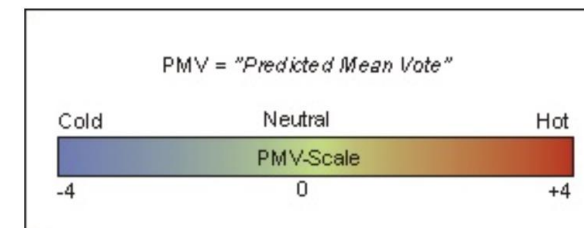


a- The four points in the Modern Residential urban fabric- Raqaib 2, that was used for validation (Al Raqaib housing map, 2021)

b-Extech 45170 meter (Extech, 2021)



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



Outdoor PMV scale outdoor areas (PMV-ENVI-met, 2021)





## C- Simulation and Analysis conditions

- For both case studies ( old and new districts ) a plot about  $160 \times 160 \text{m}^2$  was defined for simulation and analysis .
- The simulation was conducted for each model for 24 Hrs. on the 21<sup>st</sup> of August .
- There were some shared fixed data for both urban fabrics of the case studies including : Building materials, Location and climatic data as the hot arid UAE,. While there were independent features and data for each case study's such as : the urban layout ,Streets width, orientation and geometry

### Case studies main features

#### Ajman Heritage district

#### Al Ragaib modern district – (SZHP)

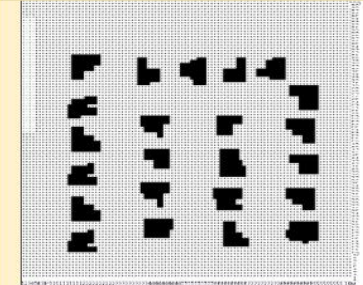
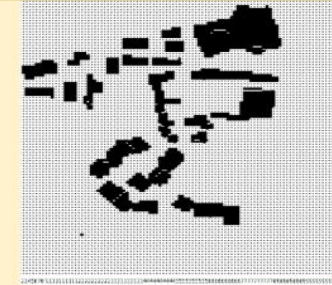
#### District layout



#### Plot area built-up area

Plot area=  $160 \times 160 = 25600 \text{ m}^2$

Plot area=  $160 \times 160 = 25600 \text{ m}^2$



#### Built-up area

Built up area around  $11500 \text{ m}^2$

Built up area around  $11500 \text{ m}^2$

#### 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 towers (Brajeel) 12m

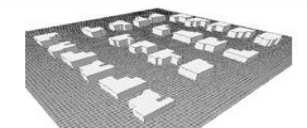
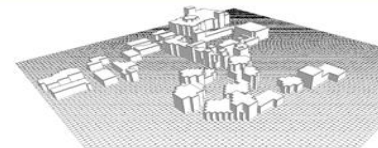
Two floors 8m

#### Buildings type

Semi-attached houses

Residential-detached houses

#### 3D geometry



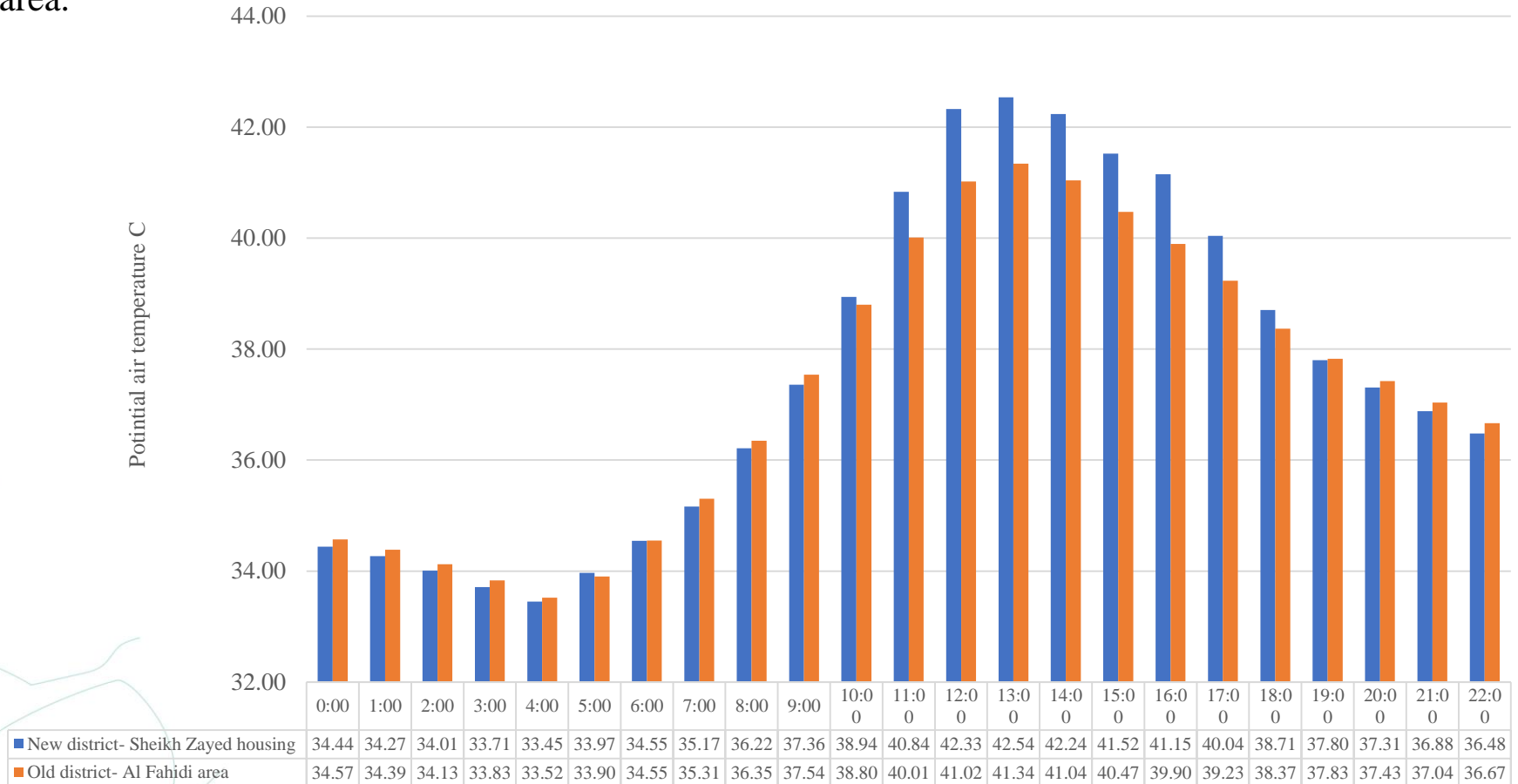


### 3. Simulation Results, and Discussion



#### Thermal conditions comparison for the old and new districts

- The simulation outputs revealed that there was a variation in the air temperature data between the traditional and the modern cases studies.
- The traditional case study – **Ajman heritage area** , presented lower readings for the air temperature, especially from 10 A.M. to 5 P.M. on the time of the peak hot hours in that area.
- Mostly that was because of the nature of traditional area design , which has more compacted lay out , narrower streets and semi opened courtyards which generated additional shaded areas with lower readings for the potential air temperature.





➤ The hourly data for both cases presented more clear differences, for instance at 13:00 pm as one of the hottest hours of the day on 21<sup>st</sup> of August, 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 C° and the maximum was around 42.53C° .

➤ Based on simulation the old district had lower minimum air temperature reading with about 0.49°C and a lower maximum air temperature reading with about 1.35°C.

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	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00
Min	33.62	33.62	33.46	33.23	32.98	33.41	33.84	34.32	35.51	36.82	38.15	39.70	41.15	41.17	40.82	40.02	40.08	39.28	38.45	37.63	37.13	36.68	36.26
Max 1	35.26	34.92	34.56	34.19	33.92	34.52	35.25	36.01	36.92	37.90	39.73	41.97	43.50	43.90	43.65	43.02	42.22	40.80	38.96	37.97	37.49	37.08	36.70
Avg.	34.44	34.27	34.01	33.71	33.45	33.97	34.55	35.17	36.22	37.36	38.94	40.84	42.33	42.54	42.24	41.52	41.15	40.04	38.71	37.80	37.31	36.88	36.48
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	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00
Min	33.91	33.79	33.49	33.15	32.80	33.24	33.80	34.51	35.73	37.17	38.17	39.11	39.93	40.15	40.09	39.84	39.47	38.92	38.16	37.70	37.28	36.85	36.44
Max-2	35.23	34.98	34.76	34.51	34.24	34.56	35.30	36.10	36.97	37.91	39.43	40.91	42.11	42.53	41.99	41.10	40.32	39.54	38.57	37.95	37.57	37.22	36.89
Avg.	34.57	34.39	34.13	33.83	33.52	33.90	34.55	35.31	36.35	37.54	38.80	40.01	41.02	41.34	41.04	40.47	39.90	39.23	38.37	37.83	37.43	37.04	36.67

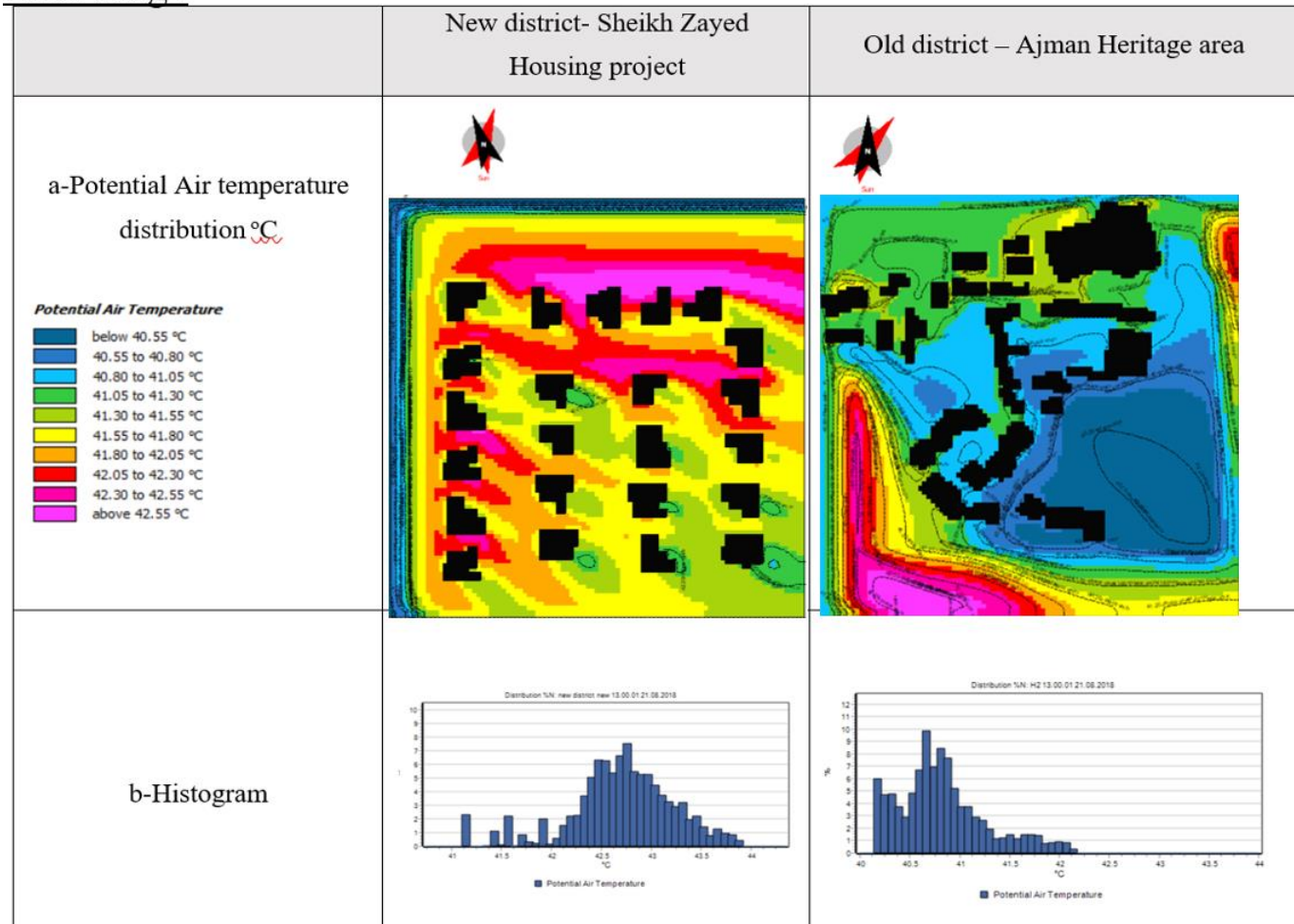


The potential air temperature pattern distribution on the 21<sup>st</sup> of August at 13:00 pm and at height of 1.8m indicated that :

- The old district showed lower and better air temperature distribution than the new one, despite the fact that both areas had built up area to plot area is around 45%, that can be explained as the following :

- The old heritage area had organic and semi-attached structure with relatively compacted structure and that produced additional shaded zones, which assisted in reducing the potential air temperature in it, opposing the new district, as the buildings were detached and totally separated and distributed regularly according to grid structure and that reduced the amount 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.

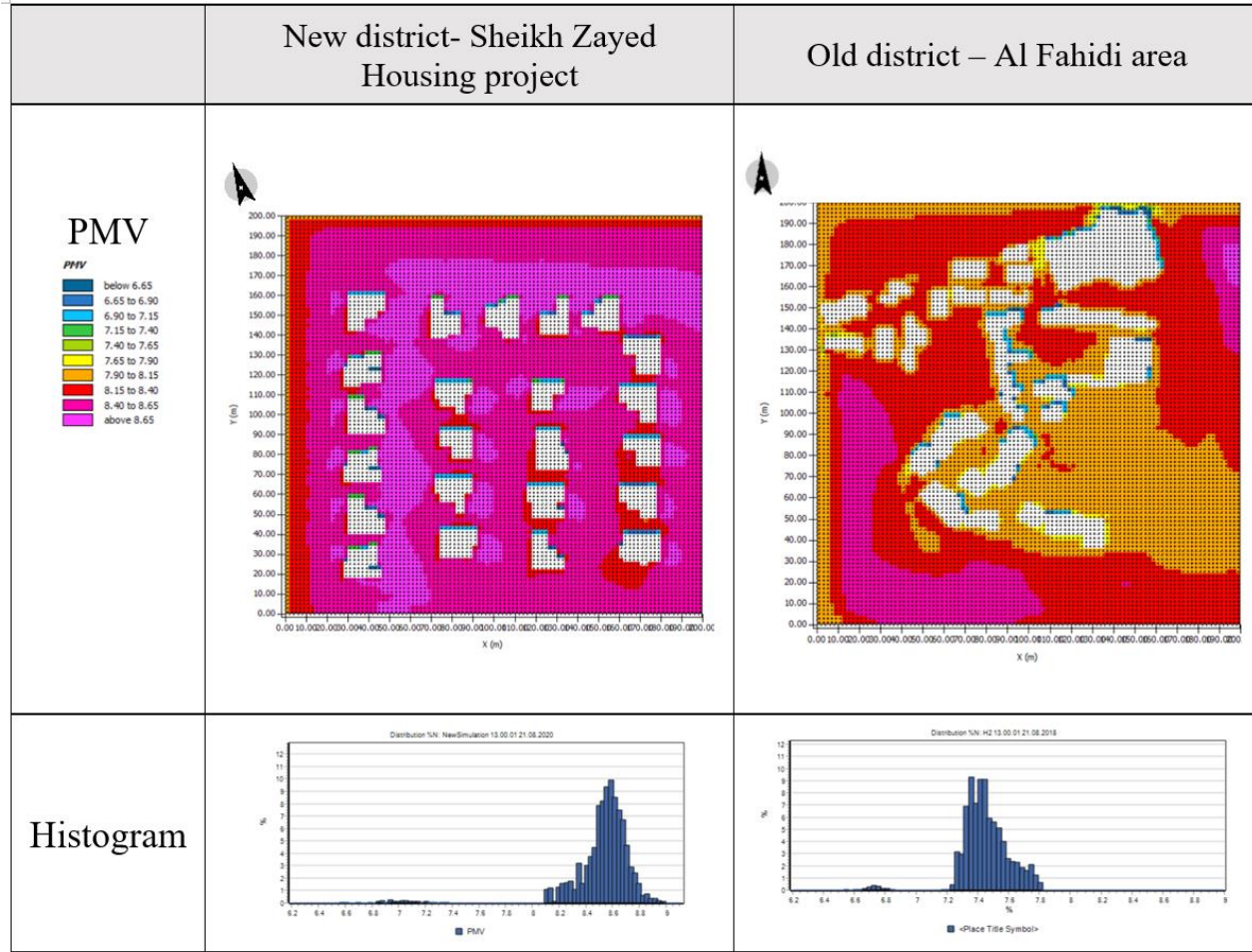




➤ PMV ( Predicted mean vote ) for the thermal comfort sensation was investigated for both old and new districts on the 21<sup>st</sup> of August at 1:00 pm and the results were illustrated **in the side figure .**

➤ It was clear that the range of PMV readings in the outdoor areas in the **old district** fluctuated between 6.12 – 7.69 on PMV scale , and these readings were lower than the related readings in the **new district** , which had 6.37 - 9.01 PMV readings .

➤ **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 concentrated around 7.4, as they were lower than readings for the related levels for the new district which were concentrated around 8.6. level.**





## 4- Proposals for enhancing the thermal settings in the Sheikh Zayed Housing project – New district



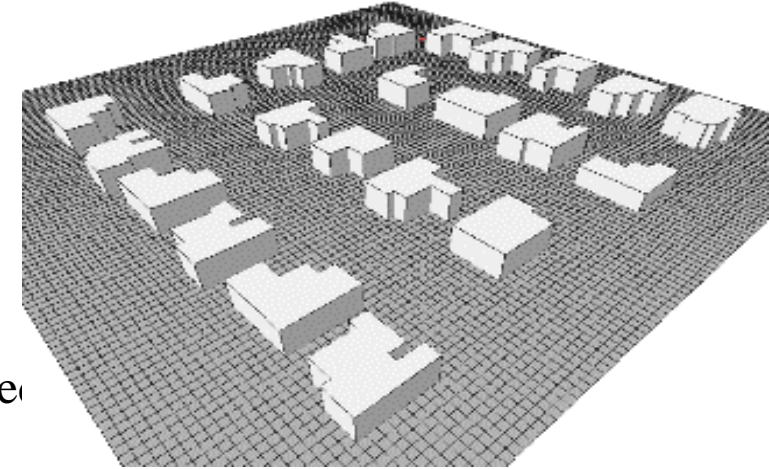
- The results for the previous analysis indicated better thermal environs in the **old district** - Ajman heritage area compared to the **new district** - Sheikh Zayed housing project in Ajman mainly due to the semi connected irregular buildings' masses , narrow pathways and courtyard as passive traditional solutions that created more shaded areas .
- The shaded areas improved the air temperature in the outdoor spaces .
- Based on and guided by the better thermal conditions in 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 in it.





The strategies for increasing the shaded areas in the **new district** as a passive sustainable design solutions ( inspired from the heritage **old area** ) faced some concerns, that these solutions should be integrated to an **existing new** built up neighborhood urban design 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 are designed according to the municipality built up regulations maximum width of streets and pedestrian reaches up to 15m.
2. **It was not applicable** to change the direction and the grid pattern 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 as 4 m from all sides of the 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 .





## Adopted solutions for enhancing the thermal settings in the Sheikh Zayed Housing project – New district

It was clear that the proposed passive solutions to improve the urban thermal settings in the **new district** should be applicable to the constructed buildings and the general regulations for the urban layout without any manipulation in the buildings masses or streets and urban layout , for instance

1- adding shading devices in front of buildings and in the open outdoor gathering area

2- or adding green hedges to increase the shaded extents in the new district

Cases	Specifications for unbuilt areas	Image	3D View
Base case for Sheikh Zayed Housing Project 	Brick road (red stones)- sidewalks and pathways 100%		
Solution -1: Hedges 	Brick road (red stones), sidewalks and pathways (80%), and hedges 20%		
Solution -2: Green Shading Devices 	Brick road (red stones), sidewalks and pathways (90%), Green Shading devices 10 %		



➤ The results of the simulation for the two proposed solutions showed variation in the average potential air temperature per hour with differences between the Max, Min and average readings between the **new district base case** and the proposed two solutions on 21<sup>st</sup> of August.

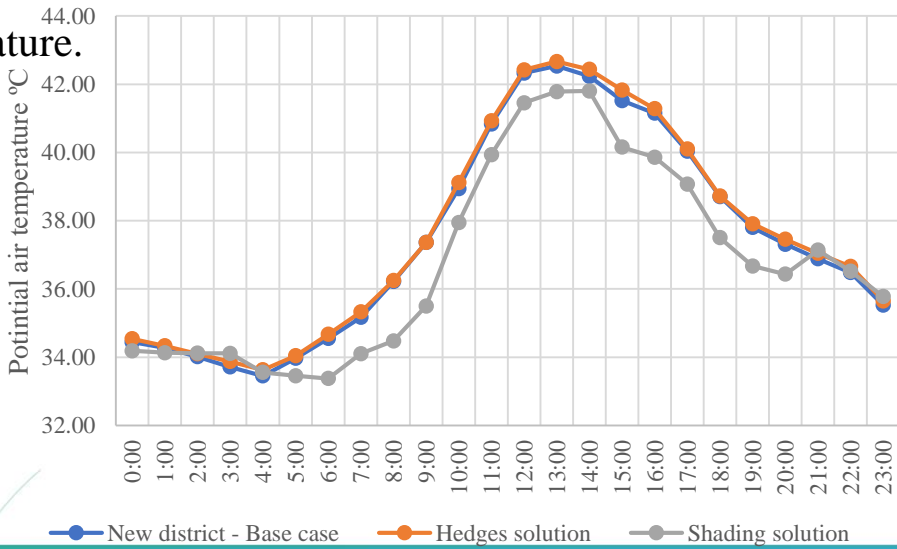
➤ For instance at 13:00 pm, the **base case** had max air temperature reading 43.9°C, min 41.17°C and Av. 42.54°C, while for the first solution – **Hedges** the max reading was 44.25°C, min 41.08°C with Av. 42.67°C, and for the second solution- **Shading devices** the max reading was 43.08°C, min 40.49°C with Av. 41.8°C, based on the that the readings for the second solution – shading devices were the best.

➤ As adding the shading devices in the new district succeeded in reducing the potential air temperature readings for the max by 0.82°C, min 0.68°C, consequently reduction in the Av. By 0.75°C.

➤ Despite the fact that the reduction in the readings were not very high but they presented a good

➤ potential in improving the urban outdoor air temperature.

Time	Shadin	Hedge	New district
0:00	34.185	34.53	34.44
1:00	34.13	34.33	34.27
2:00	34.115	34.09	34.01
3:00	34.11	33.87	33.71
4:00	33.55	33.62	33.45
5:00	33.455	34.04	33.97
6:00	33.375	34.67	34.55
7:00	34.1	35.32	35.17
8:00	34.475	36.24	36.22
9:00	35.5	37.36	37.36
10:00	37.945	39.12	38.94
11:00	39.935	40.92	40.84
12:00	41.455	42.42	42.33
13:00	41.8	42.7	42.54
14:00	41.8	42.43	42.24
15:00	40.155	41.83	41.52
16:00	39.86	41.28	41.15
17:00	39.07	40.1	40.04
18:00	37.5	38.72	38.71
19:00	36.67	37.91	37.80
20:00	36.43	37.45	37.31
21:00	37.135	37.04	36.88
22:00	36.515	36.65	36.48
23:00	35.775	35.65	35.52



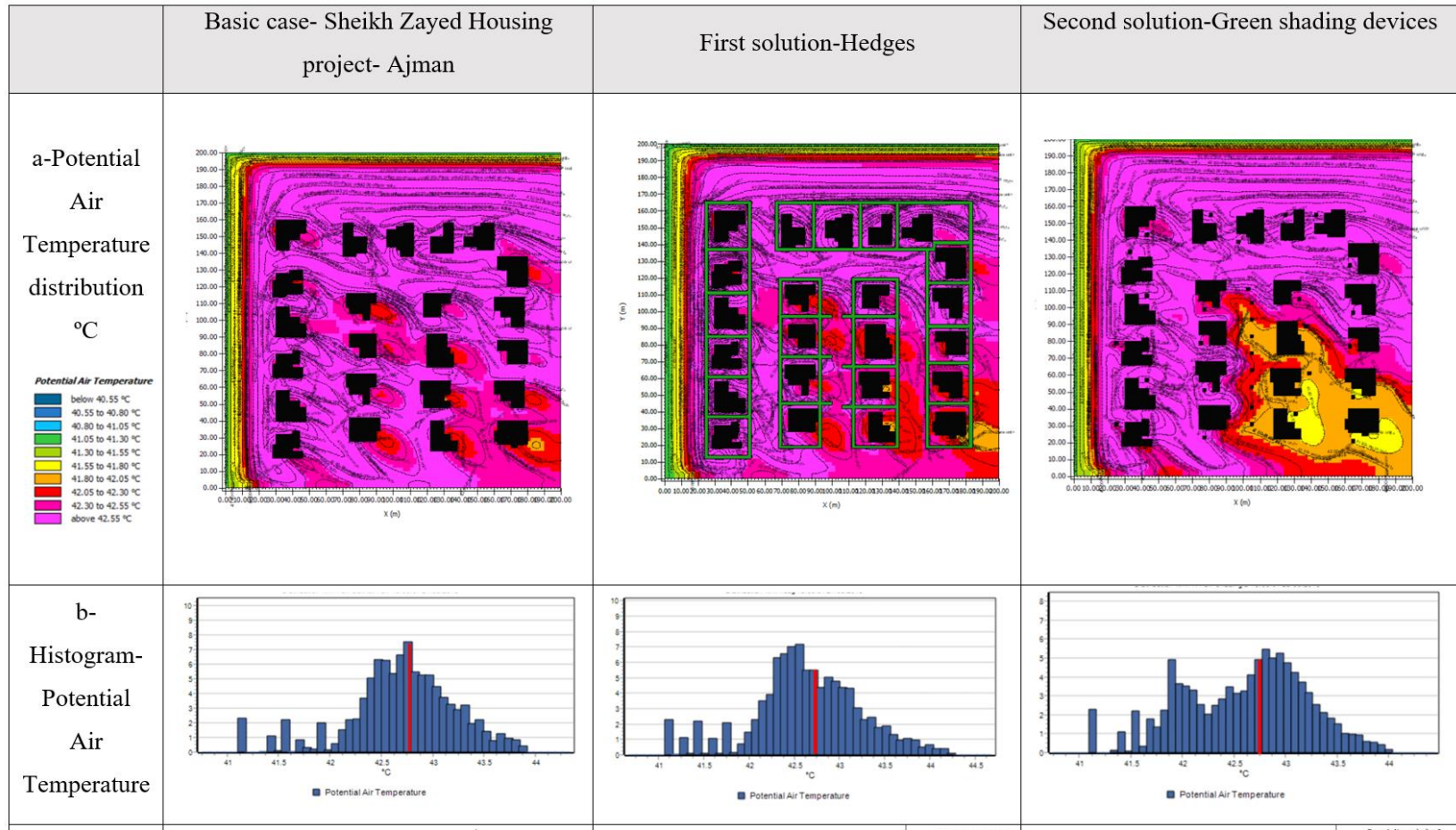
a- Max and Min potential air temperatures for the base case and the solutions at 13:00 pm on 21st of August.



- Looking at the air temperature distribution on 21<sup>st</sup> of August at 13:00 pm, it was clear that the first solution - **hedges** improved the general thermal performance of the area but in a level less than the second solution – **shading devices**.
- As the second solution - **shading devices** had the lowest air temperature distribution compared to the **base case** and the first solution, based on that the potential air temperature in the southern west part changed from above 42.55 (purple colour) to range between

➤ 41.55-41.80(yellow colour) and that due to the new created shaded areas that helped in lowering the air temperature and improved the thermal performance for the whole district, beside that these shading devices improved the air circulation because of the new air temperature differences which created difference in the air pressure.

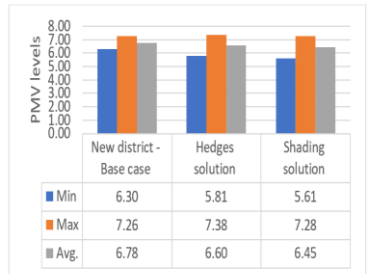
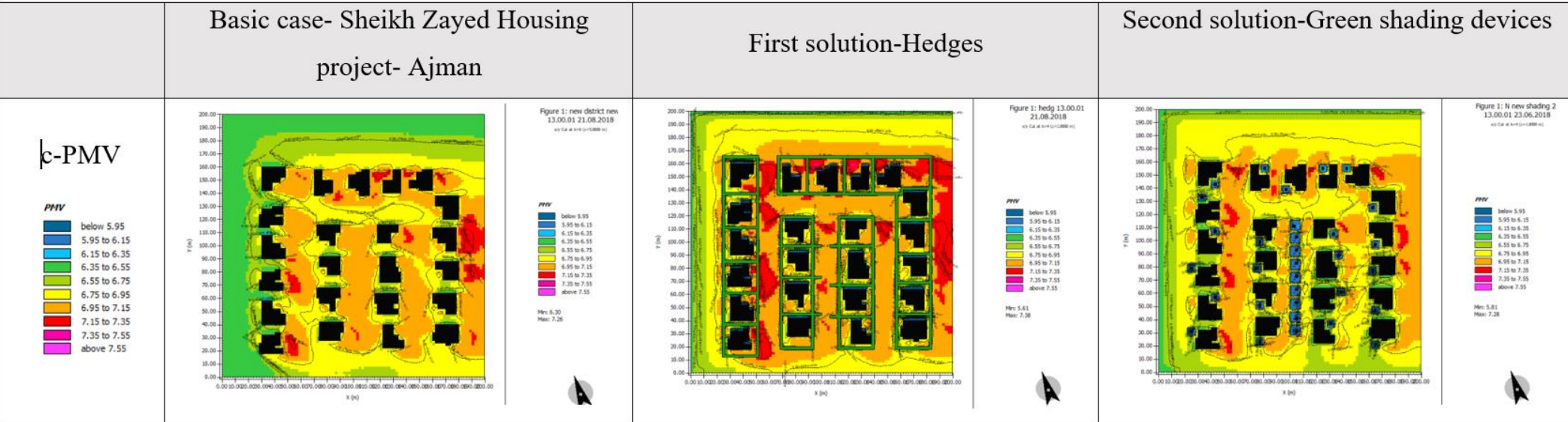
The shading devices succeeded in copying and mimicking the traditional old district by creating more shaded areas between the buildings and in the public open space.





**The reduction in the air temperature affected positively the Predicted mean vote – Thermal comfort prediction- PMV**

- There was reduction in the PMV readings by adding the **shading devices** with 0.67 level for the max and 0.33 for the Av. Compared to the **base case** PMV readings. As the levels for the **base case** were ranged between 6.30 – 7.26 and it was higher than the proposed solutions , because 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 , nevertheless the PMV readings created by the second solution for the new succeeded in improving the general outdoor thermal comfort for the users .



b- Max and Min PMV levels for the base case and the solutions at 13:00 pm on 21st of August



## **Conclusion** Traditional architecture is a good sustainable example to follow

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- The old traditional architecture presented a good capability in handling the climate effects as it was an environment responsive Architecture, while the modern contemporary architecture focused on the style, despite the urgent need for sustainability.
- This study investigated the effect of the traditional architecture and urban design layout in creating sustainable microclimate and thermal comfort for the users in hot arid areas to extract the positive urban design ideas and benefit from them in improving the modern urban design fabrics.
- The study analyzed and simulated the old district in the traditional old fabric to conclude solutions for the thermal performance in the modern urban fabric by increasing the shade and decreasing the outdoor temperature.
- The study found that adding green shading devices in the vacant land in the modern urban fabric helped in improving the outdoor temperature better than adding hedges with clear reduction in the air temperature distribution.
- Finally, the study found that whenever there was a reduction in the outdoor temperature in hot areas, there is an improvement in the PMV levels.
- **The study can be a step among many steps that can help architects and urban designers to benefit from the concepts of the vernacular urban designs and integrate them in the modern urban fabric.**





Dr. Muna Salameh

Thank you

Ajman University

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Member of the Supreme Council and Ruler of Ajman

Municipality and Planning Department-Ajman is pleased to organize

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Monday & Tuesday, 28 -29 March 2022 at Sheikh Zayed Centre for Conferences  
and Exhibitions of Ajman University of Sciences and Technology (AUST) Campus in Ajman,

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