Optimizing the Performance of Public Open Spaces by Enhancing the Human Thermal Comfort

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1 ABSTRACT

Outdoor human comfort is a key parameter in the evaluation of city's liveability. In addition, it helps in promoting people's health and well-being, leading to the improvement of quality of life. Egyptian cities are impacted by urban heat island due to the dense urban fabric causing an obvious deterioration in the quality of their public spaces. Open public spaces provide various benefits to citizens; as they may intensify the economic, social and environmental aspects of the urban environment. Unfortunately, some cities' open public spaces are unattractive to human activity due to the challenges they face. The enhancement of microclimatic conditions in urban spaces can enable people to spend more time outdoors, with the potential to influence the social cohesion of a space and increase in the economic activity.

Therefore, the wider aim of this research is to develop a better understanding of the complex relationship between the microclimate and human behaviour. The study focuses on the open public spaces in Alexandria city's hot arid climate, It is intended to study the effects of socio-economic and cultural diversity on thermal comfort, behaviour and use of space. Field surveys are carried out during the summer of 2019 (19th of August). All of the surveys include, observations of human activities and clothing, along with microclimatic monitoring. The analysis consists of; microclimatic influence on thermal sensation, people attendance; and investigation of socio-economic and sociocultural characteristics for each space. The process is carried out in order to propose a set of recommendations and mitigation strategies, suitable to deal with public spaces. This set is driven by studying the prospects of successfully designed public spaces and mapping the variations in the environmental conditions using ENVI-met and RayMan software in two selected public spaces in Alexandria as a case study.

Keywords: Thermal Comfort, Public Spaces, Mitigation Strategies, Quality of Life, ENVI-Met

2 INTRODUCTION

2.1 City Overview: The Current Built Fabric

The situation of public spaces, specifically in developing countries has been a major issue of debate. The idea of public spaces has been a topic of great discussion in spatial as well as in social aspects, examining how places are successful in achieving a vital urban environment. Public spaces contribute in the general wellbeing socially and spiritually(Attia 2011). As the number of inhabitants in urban areas increase, the need for successful public spaces within cities increase too. Open spaces provide enclosure for all people in which they are free to use without permission or justification, in addition to, practicing their rights as citizens for gathering or recreation(Aljawabra and Nikolopoulou 2010). They are related with shaping the image of urban settlements in which they interpret both the physical setting and the distribution of activities. This role is intensified within city centres. Public open spaces become of particular significance, they are regarded as a fundamental component of the public realm, and as an important public facility (Abdel-Salam 1996; Gehl 2010). Alexandria, the second largest city in Egypt, and its main port on the Mediterranean Sea. It has continuously gone through varying social and economic conditions since it was established in 331 BC. The city started to develop from the early 19th century under the European influence until its current condition as one of the most cosmopolitan cities of the Middle East. Alexandria became an attraction point to nearly 3 million visitors each summer which increases its importance as a touristic city. The open space typology consists mostly of longitudinal roads with orientation east-west, parallel to the harbour, and perpendicular streets on them from north to south. Squares are only located on the borders of the area. Central streets, with width less than 20 m, are defined by continuous lines of buildings with varying heights creating an enclosure forming linear outdoor space. These streets have the functions of allowing people to move around, in addition to offering the only available outdoor space for other recreational purposes (Abdel-Salam 1996).

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Fig 1: The Main streets network in Alexandria's old districts (source: Researchers)

2.2 Problem Definition

The relationship between people and space outlines the identity and image of the city, which can be lost if this relationship is degraded. Unfortunately, the traditional function of city space as a meeting place and social forum for city dwellers in the Arab countries specifically has been threatened (Attia 2011; Gehl 2010).Considering the effect of public spaces in enhancing the quality of social life ,in many Arab cities, the public spaces designed and constructed aren't responsive to social needs and the improvement of the relations between citizens(Mehan 2016). Public spaces in Egypt suffer from great deterioration physically and functionally due to the lack of maintenance, informal street vendors, in addition to poor urban design, neglecting the basic human outdoor needs leading to pedestrians' discomfort. The decline occurring at all levels within Alexandria's districts, residential communities, public gardens, and even public squares, is the result of the place-making approach that has taken a firm ontogenetic approach , which was defined in (Kropf 2001)'s Conceptions of Change in the Built Environment as: the development of the physical form of single separate objects in their physical shape or condition, rather than its spatial type. However, this mode of development, limits the capacity for human flourishing and community led change, where this type of change for public spaces is chosen by the government and decision makers regardless the involvement of citizens' requirements. Public participation guarantees the consideration of human dimension and basic needs, making public spaces more liveable and user-friendly. Although spatial design can be a fast facilitator towards successful community spaces "physically", it can also produce controlled spaces with limited accessibility, consequently compromising people's rights to occupy publicly owned space. This might be due to the irrelevancy of the applied strategies to some spaces rather than others, as they have different characteristics concerning their morphology, location, function, type of users and social and cultural aspects which must be considered. This problem is greatly reflected in Alexandria's street patterns and the use of space, as well as the physical and social elements that can also form boundaries between private and public spaces.

2.2.1 Thermal Comfort in Public Open Spaces

Thermal comfort is an important parameter in enhancing the utilization of open public spaces(Cheung and Jim 2019; Lai et al. 2014) because their benefaction is associated with the outdoor thermal condition(Cheung and Jim 2019; Coccolo et al. 2016). Therefore, Optimizing the thermal condition of urban public spaces is crucial to the success of landscape design and urban planning(Blazejczyk et al. 2012; Cheung and Jim 2019). Public spaces with high quality encourage people to stay longer with the opportunity to practice a wide range of activities. The quality of spaces depends mainly on the degree of usage, which can be measured according to the fulfilment of citizens' needs and requirements.

High quality public spaces are an outcome for people's interaction with urban environments. Several studies stated that public spaces are one of the most important urban elements that contribute in promoting the quality of life (Mehan 2016). Public open spaces such as parks and green spaces, provide opportunities for a variety of physical activity behaviours, such as recreational walking and playing sports. Activities in the public open spaces are highly influenced by microclimate and specified by urban spatial settings (Koohsari et al. 2015).Thermal comfort is defined by (ASHRAE 2016) as “the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation”. Participants differ in their evaluation of comfort. In order to provide a valuable review for the performance of the outdoor built environment, comfort has been a primary indicator for good public space design and the assessment of its quality(Peng, Feng, and Timmermans 2019). Moreover, the culture and climate that people are used to, their emotional state, visiting purpose and their use of public spaces may potentially also link to individuals' subjective evaluation of outdoor comfort. The resting condition of individuals gives more specific evaluation of their comfort, as they spend more time than just passing by or walking through streets which does not take much time as the sitting situation (Nikolopoulou and Steemers 2003). Another key factor, the “PET” physiological equivalent tempreature, which acts as a fundamental indicator for the human thermal comfort. This has been taken into consideration. However it’s being reffered to in a later section of this paper (3.2.2).

2.2.2 Urban Heat Island Phenomenon

The UHI is a phenomenon where a difference in temperature can be observed within a city or between a city and its surrounding rural areas (Kolokotroni and Giridharan 2008; O’Malley et al. 2015) and the densest part of the urban areas are expected to have maximum temperature. Some studies propose that the impact of UHI may be more significant in small to medium- sized cities. Therefore, Alexandria city which is inhabited by over 5 million citizens and a medium size in comparison to other Egyptian cities (General agency of public and mobilization and statistics,2019), is subjected to a medium impact UHI phenomenon. Consequently, some regions in the city suffer from elevated temperatures especially at night, areas with high rise buildings, extensive use of AC and regions that lack any shading elements or vegetation, are likely to be more subjected to the phenomenon.

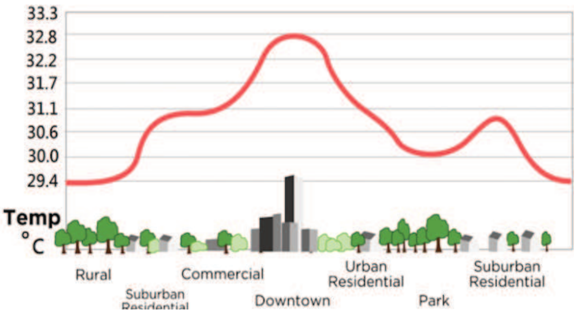

Fig 2: Typical UHI profile (source: Elgizawy 2017)

Anthropogenic heat emissions are considered on of the the main causes of UHI. Also, pollution and energy consumption within a city(O’Malley et al. 2015), intensive land use and high density in urban areas combined with buildings with high heat retaining properties can amplify this phenomenon(Harlan and Ruddell 2011). Moreover, reduced speed of wind caused by design and layout of the built environment can create urban hot spots (O’Malley et al. 2015; Santamouris et al. 2001) Furthermore, lack of green areas and presence of materials with reduced permeability(Chen et al. 2009; O’Malley et al. 2015), and presence of low-albedo materials on buildings external facades and road sur-faces (Giannopoulou et al. 2011) also are known to be the most significant causes of UHI.

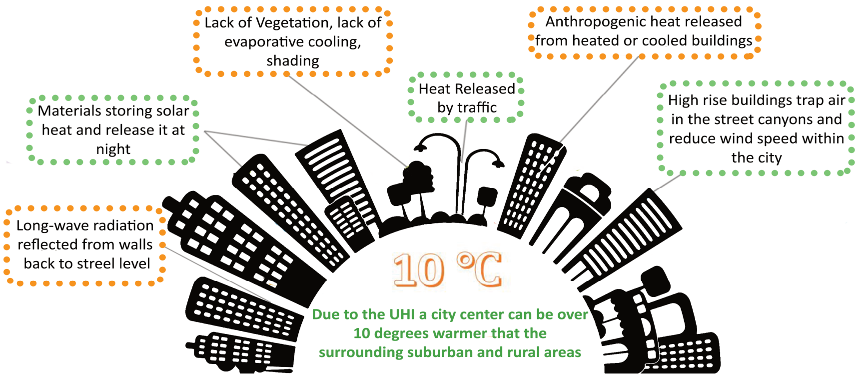

Fig 3: UHI causes, (source: Researchers, adapted from https://www.emaze.com)

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Urban heat islands do not only affect the health of the environment and local wildlife, but also the health of humans. Increased city temperatures can be fatal during summer heatwaves, particularly for senior citizens(Salata et al. 2017). Urban inhabitants also suffer during heat waves because the urban heat island prevents night-time temperatures from decreasing as they do in rural areas. Research has found that urban heat islands not only increase temperatures during heat waves but also prolong their duration(Kolokotroni and Giridharan 2008).

3 METHODOLOGY AND TOOLS

3.1 Case study Observations and Field Surveys

The observations were carried out in three selected public spaces with different demographic and physical conditions. The Roman Museum square has the best physical condition and the highest social level, while Sidi Ali Al-Temraz square which is located in a relatively poor area which has the worst condition. Measurements and observations were recorded every 3 hours starting at 12:00 AM, on the 19th of August 2019, in Alexandria, Egypt. The observations and field surveys show that thermal comfort conditions, affect people's use of outdoor spaces. Responses to the microclimate might have been unconscious but have resulted in a different use of urban space in different climatic conditions.

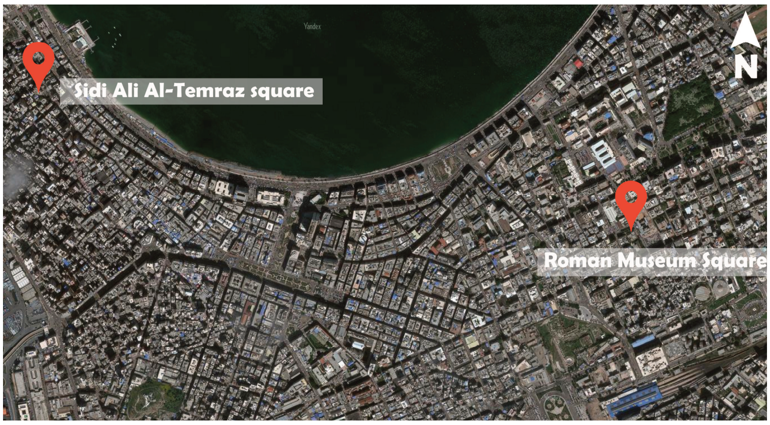

Fig 4: Location of the selected spaces for study on Alexandria's map (source: Researchers)

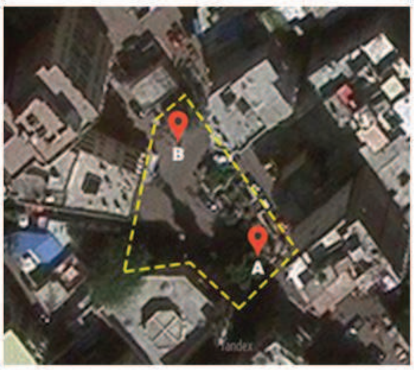

Fig 5: The selected 2 points in the Roman Museum space (source: Researchers). Fig 6: The selected 2 points in Sidi Ali Al-Temraz space (source: Researchers)

Examining the number of people using the selected spaces for study, shows that the different spaces at various time intervals, reveals that warm conditions, the presence of the sunlight and humidity are the significant factors in the use of the space. UHI showed a significant effect on the human presence which was obvious at 9:00 PM which recorded high temperatures in addition to elevated relative humidity. Moreover, the cultural, social and religious aspects which showed the absence of females at late hours of the day. Social activities were recorded as shown in Table 1 as an example, two points were selected in each space for the measurements and observations, the average was taken between each two points for the space.

The Roman Museum space is surrounded by buildings mainly corporations, while Sidi Ali Al-Temraz space is surrounded by residential buildings in addition to shops and recreational activities, therefore it was more active at night, rather than the other space which had a significant activity in the morning hours.

Time	Clothing	Activities		Number of visitors		
		Types	/10	Total	M	F
12:00 AM	average	people sitting on the sidewalks chatting car flow	5	**8**	8	0
3:00 AM	average	car flow only no sign of any pedestrian activity	0.5	**4**	0	4
6:00 AM	average	cars waiting causing traffic jams	0.5	**3**	0	3
9:00 AM	men wearing tuxedos (work /over-heat)	parking/ pedestrians/ corporation's activity	6	**18**	4	14
12:00 PM	summer light clothing for	parking/ pedestrians/car repair	7	**29**	4	25
3:00 PM	Over-dressed due to wok conditions	heavy car flow and pedestrians (end of work hours)	6.5	**12**	0	12
6:00 PM	average	car flow only / less pedestrians/ calm	6	**12**	0	12
9:00 PM	Light for males(shorts) conservative for females	mechanics repairing cars in the street making it more crowded and active	8	**29**	6	14

Table 1: The observations recorded for Point B at Roman Museum space (source: Researchers)

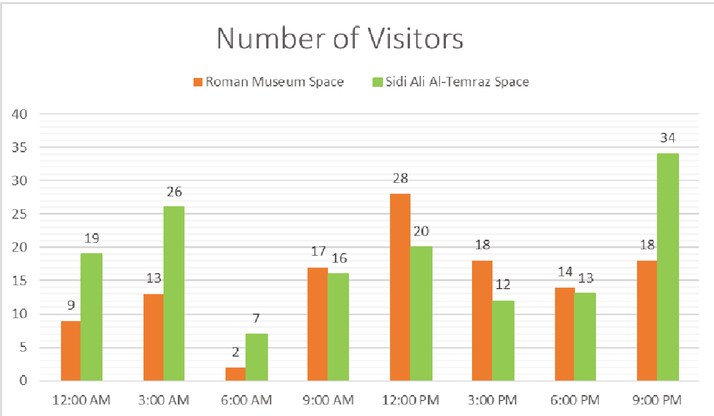

Fig 7: Total number of visitors for each space (source: Researchers)

While studying the human activity, there was more concern about resting areas, since people choose to sit somewhere, rather than a pathway which is less likely to be chosen, in order to avoid discomfort. Streets and pathways will not cause them serious discomfort, since the time of exposure to the specific environmental conditions is short. However, while resting the situation is different, as poor climate conditions may distress people and drive them to avoid using public open areas.

The bigger problem is the lack of street furniture presence, this is affecting the spaces' liveability in the case of the Roman Museum space. However, Sidi Ali Al-Temraz space is more active but in an informal way where coffee shops' owners place chairs and tables on the sidewalks, which cover the whole width. Also, randomly parked cars diminishing the space's physical dimensions.

3.2 Results and Discussions

3.2.1 Field Studies and Measurements

The environmental monitoring focuses on measuring three classical thermal parameters that are well-known for their impact on thermal sensation. These parameters are air temperature, wind speed and relative humidity. Measurements carried on one of the hottest summer days in 2019, shows that the highest relative humidity is recorded in the evening, which validates the theory that states that the UHI phenomenon is more

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obvious and affects the thermal sensation in the evening (Cheung and Jim 2019; O'Malley et al. 2015). Moreover, Air temperature with high values is recorded at noon, which makes the need for shading elements and mitigation solutions to decrease the effect of direct sunrays is crucial, in order to enhance the thermal comfort and encourage pedestrians to spend more time outdoors.

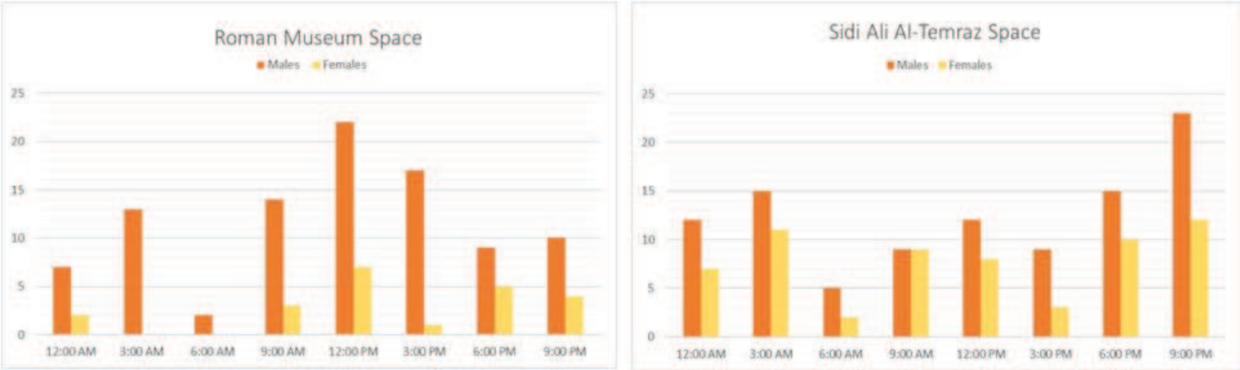

Fig 8: Classification of visitors according to gender for each space (source: Researchers)


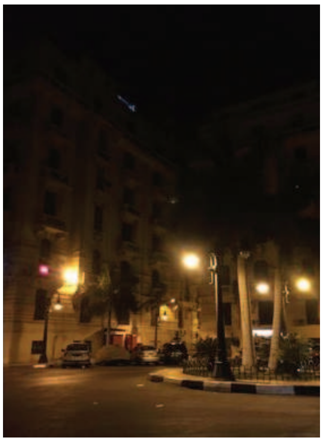

Fig 9: Roman Museum space during day hours showing medium activity, cars parked (source: Researchers). Fig 10: Roman Museum space during night hours showing nearly no activity, cars pass by only (source: Researchers). Fig 11: Sidi Ali Al-Temraz space in the morning showing activity, people going to work, and cars parked randomly (source: Researchers). Fig 12: Sidi Ali Al-Temraz space in the evening showing high activity, people sitting, walking and also cars parked randomly causing chaos (source: Researchers)


Fig. 13: fisheye lenses used for mobile phone (source: Researchers). Fig.14: Testo device used for measuring Wind Speed, RH and Air Temperature (source: https://www.testo.com/en-US/products/)

3.2.2 Physiological Equivalent Temperature "PET"

It is the air temperature of a reference environment in which the heat budget of the human body is balanced with the same core and skin temperature as under the complex outdoor conditions in the environment to be assessed. Ranges between (18 - 24°C)(Evola et al. 2017).

"PET" is a popular thermal index which have a scale classified into nine thermal stress categories designed for outdoor thermal assessment. It integrates the effects of all physiologically relevant weather parameters (Air temperature, relative humidity, wind speed and mean radiant temperature) and personal parameters (metabolic rate and clothing insulation level) to a single temperature index (Cheung and Jim 2019).

Time	Air Temperature □			Wind Speed m/s			Relative Humidity %		
	Max.	Min.	Average	Max.	Min.	Average	Max.	Min.	Average
12:00 AM	28.9	28.3	28.3	0.4	0	0.1	65.1	63.1	63.4
3:00 AM	28.5	27.9	28.5	0.6	0	0.5	60.3	54.4	68.5
6:00 AM	28.8	28	28.5	0.7	0	0.4	61.1	59.1	59.9
9:00 AM	29.1	28.9	29	1	0	0.6	57.4	40.3	56.3
12:00 PM	39.6	37	38.5	0.7	0	0.6	39.6	38.7	39.5
3:00 PM	36.3	34.4	34.7	1	0	0.8	45.7	42.5	43
6:00 PM	28.6	28.4	28.6	1.2	0.4	0.7	65.6	48.5	62.2
9:00 PM	30	29.4	29.9	1.3	0	0.8	62.5	59.7	62.2

Table 2: Point B, Roman Museum Space, On-site measurements (source: Researchers)

PET	Thermal perception	Grade of physiological stress
	Very cold	Extreme cold stress
4°C	Cold	Strong cold stress
8°C	Cool	Moderate cold stress
13°C	Slightly cool	Slight cold stress
18°C	Comfortable	No thermal stress
23°C	Slightly warm	Slight heat stress
29°C	Warm	Moderate heat stress
35°C	Hot	Strong heat stress
41°C	Very hot	Extreme heat stress

Table 3: "PET" Ranges (Source: https//: www.semanticscholar.org)

3.2.3 RayMan Software

The "RayMan" model, which appears in (Fig.14), is developed to calculate short wave and long wave radiation fluxes affecting the human body. "RayMan" estimates the radiation fluxes and the effects of clouds on short and long wave radiation fluxes. The model, which takes complex building structures into account, is suitable for various planning purposes in different micro to regional levels(Matzarakis and Rutz 2006).

Time	Roman Museum		Sidi Ali Al-Temraz	
	point A.	Point B	point A.	Point B
SVF	0.667	0.526	0.577	0.592
12:00 AM	24.2	24.4	24.1	25
3:00 AM	24.5	24.3	23.4	24.6
6:00 AM	24.6	23.2	24.1	24.8
9:00 AM	25.6	25.7	25	25
12:00 PM	26	28.6	31	31.1
3:00 PM	28.3	27.8	28.8	30.6
6:00 PM	27.7	26.8	26.3	24.7
9:00 PM	24.7	25.5	25.7	25.8
12:00 AM	24.8	25	24.4	25.4

Fig.15: Silhouette of fisheye photos for the 2 spaces (Source: Researchers). Fig. 16: RayMan software user interface (Source: Matzarakis and Rutz 2006). Table 4: The output of "PET" values for each point from RayMan (source: researchers)

"RayMan" is capable of generating the "PET" for a specific location at any time of the day, it could be done by calculating the "Sky view Factor" for the selected area of study, which was done within the study. "SVF" is generated by importing a silhouette of a fisheye photo for the open sky created through photoshop CC, the top of the fisheye photo is directed to the north direction. In addition to the fisheye photo, the on-site measured environmental parameters are added (Table 2). The purpose of this process is to obtain a table of the expected "PET" values measured in ℃ for each of the selected spaces at each hour of the study. The generated table acts as a reference to follow when re-designing an urban space, which should be reached, in order to achieve the human thermal comfort, consequently making it more appealing to human activity.

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3.2.4 ENVI-Met Simulation

ENVI-Met is a prognostic model based on the fundamental laws of fluid dynamics and thermodynamics. It also provides the evaluation of the interrelation between buildings, vegetation and various surface coverings, and of their effects on the perceived microclimate (Evola et al. 2017). ENVI-Met is used in the study to provide an adequate simulation for the current climatic situation of both studied spaces, in order to locate the spots with highest temperature and humidity which cause discomfort.

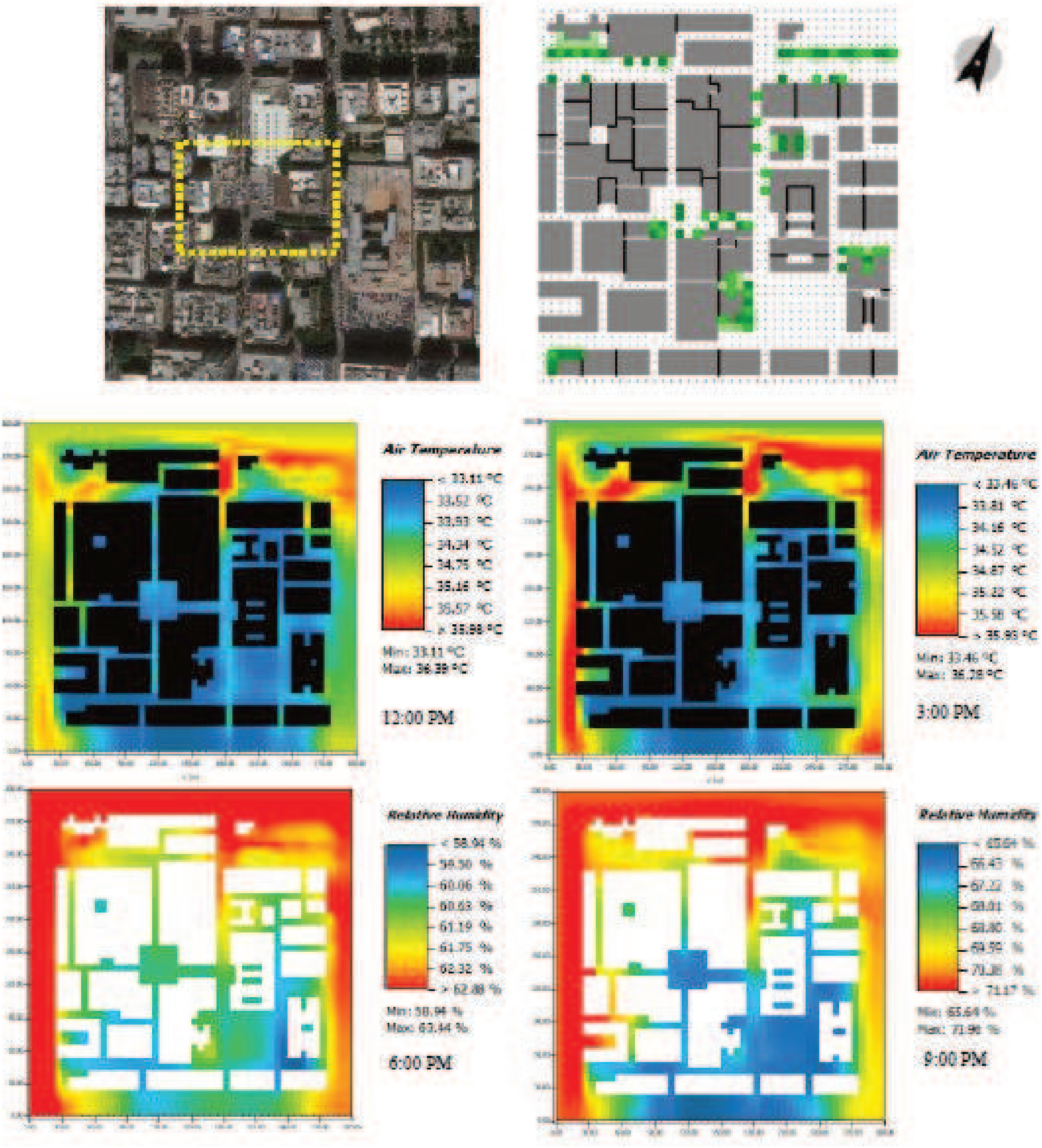

Fig17: ENVI-Met Simulation for the current situation of Roman Museum space

3.2.5 Pilot Study of Mitigation Prospects

All the current studies state that the most-promising strategies that help to reduce the UHI effect are urban green (trees and vegetation), cool roofs and cool pavements. The benefits of vegetation are obvious since it provides shadow, it introduces a cooling effect owing to the evapotranspiration, and increases the overall albedo (Evola et al. 2017). For evaluating the impact of possible actions that can be carried out to diminish the adverse microclimate effects, different mitigation actions have been evaluated, which involve the adoption of cool pavements and green elements in the recognition of the high thermal stress spots in both spaces. The reasons behind the selection of the previously mentioned strategies can be listed as, First, the selected strategies are among the most common design solutions preferred by urban planners, architects and landscape architects. Moreover, they are favoured by the general public, or at worst they are the least objected solutions by the general public for their limited impact on the plethora of different elements, issues and determinants in urban spaces. And finally, they seem to be the most affordable strategies both at the design stage technically, financially and aesthetically. The proposed strategies show a significant improvement in the air temperature and relative humidity based on the ENVI-Met simulation shown in (Figure 19 & 20).

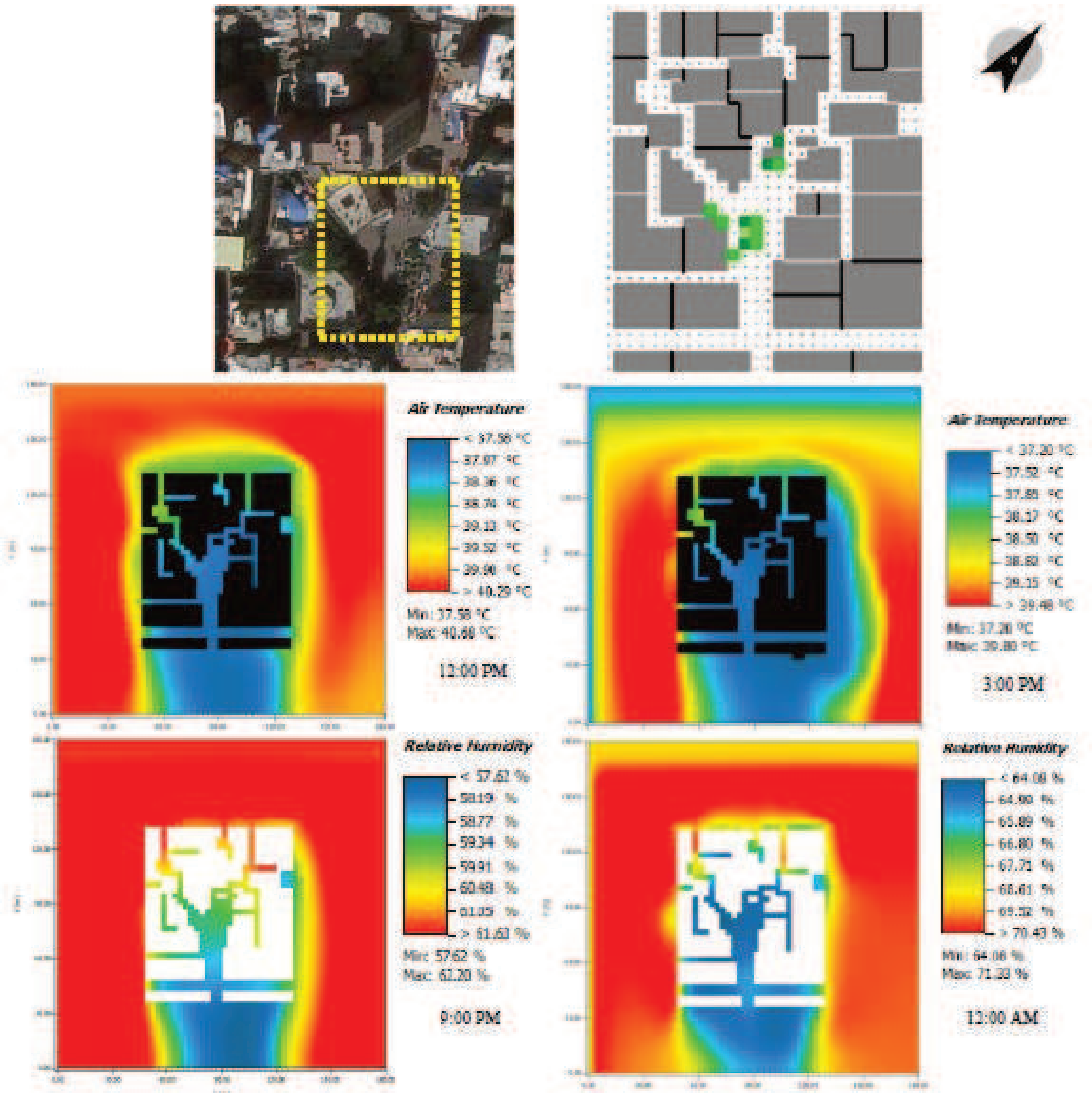

Fig 18: ENVI-Met Simulation for the current situation of Sidi Ali Al-Temraz space

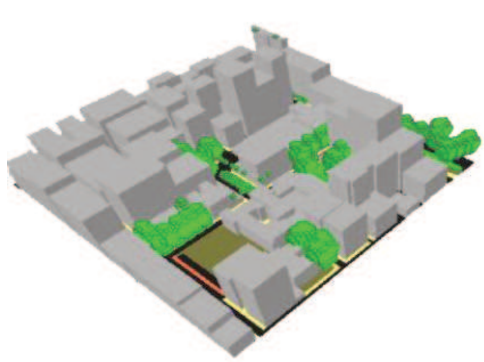
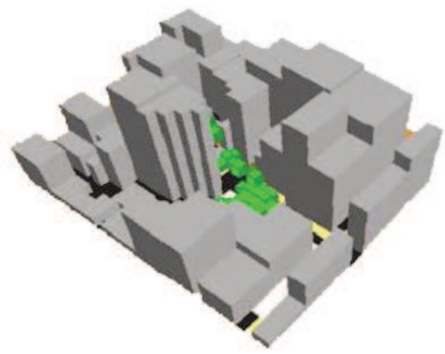

Fig 19: 3D Model using ENVI-Met for the proposed mitigation scenario for the Roman Museum Space. Fig 20: 3D Model using ENVI-Met for the proposed mitigation scenario for Sidi Ali Al-Temraz Space

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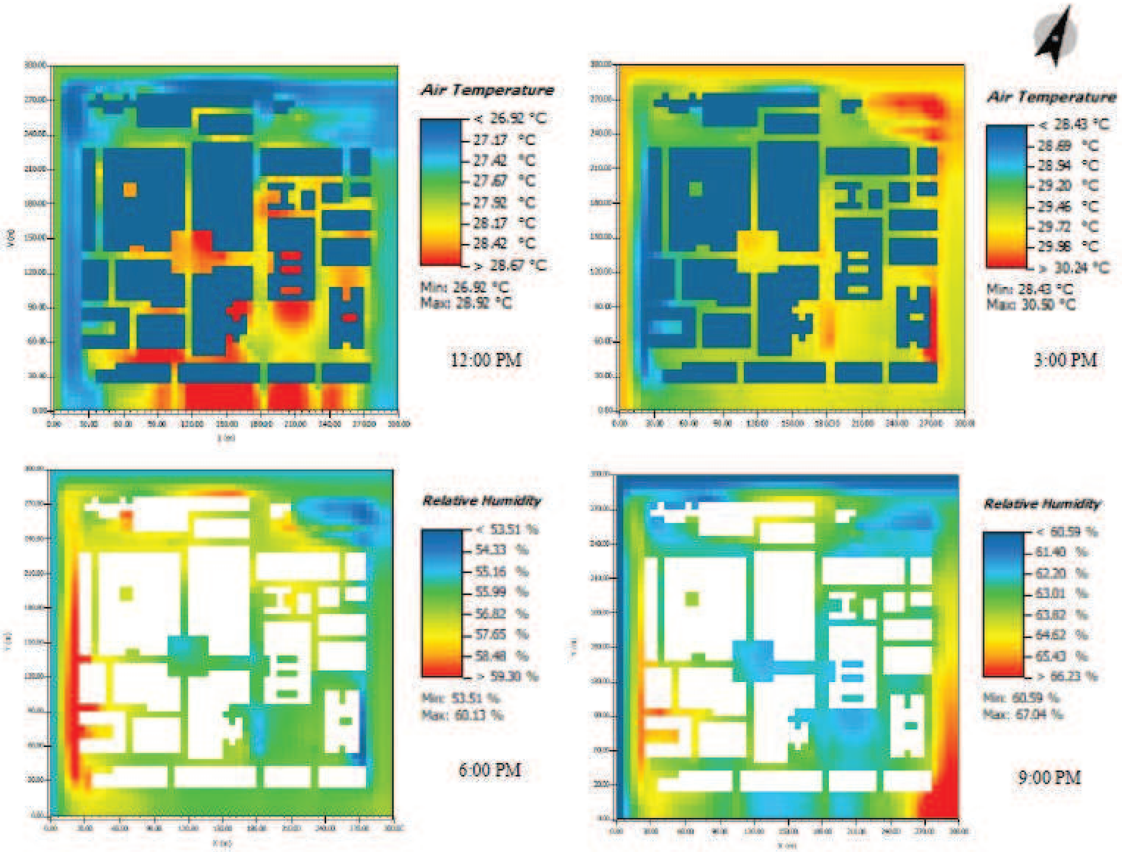

Fig 21: ENVI-Met Simulation for the proposed mitigation strategy for The Roman Museum space

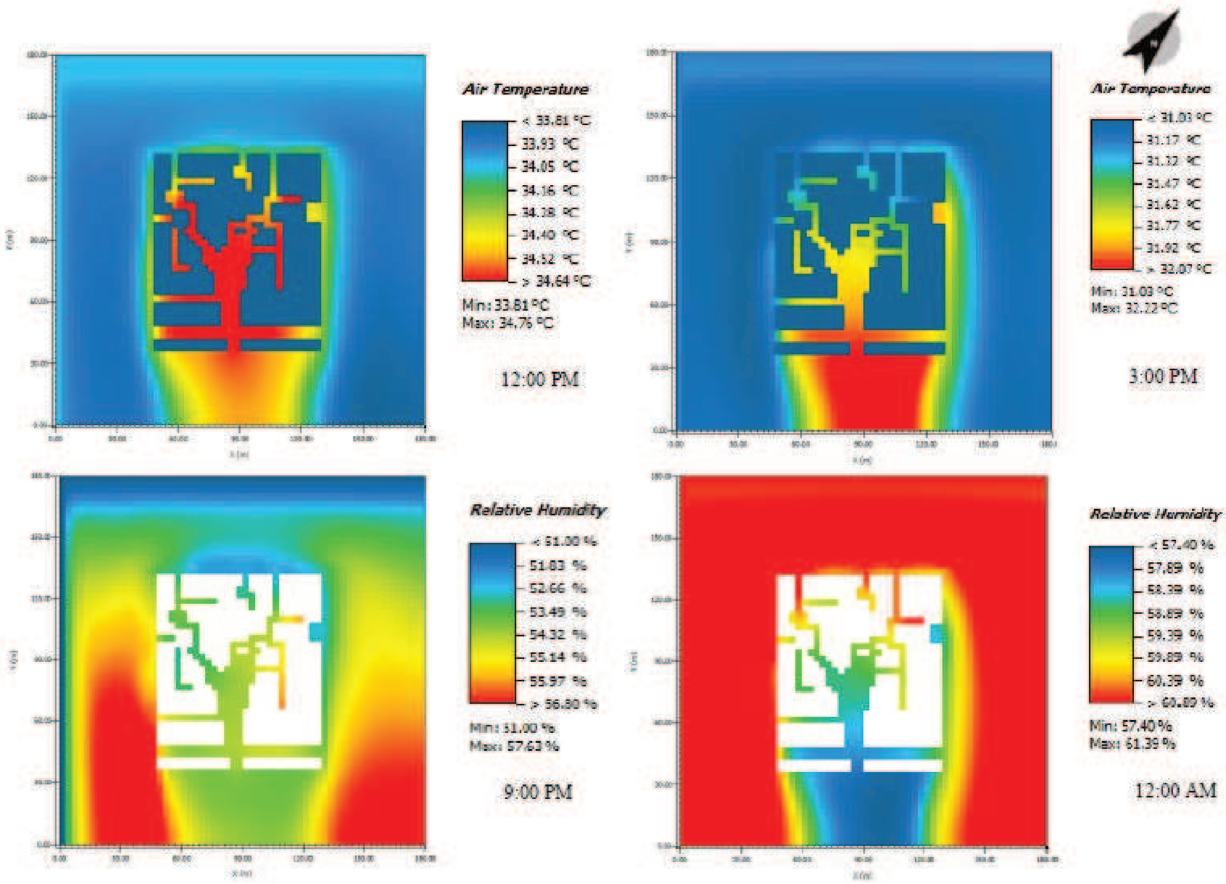

Fig. 22: ENVI-Met Simulation for the proposed mitigation strategy for Sidi-Ali Al-Temraz Space

4 CONCLUSION

This paper has focused on the complexity of parameters affecting the thermal comfort in outdoor urban spaces, particularly in areas recognised as resting places, contrary to walking pathways. The study has included a concurrent meteorological measurement and human activities observation, surveys were carried out in 2 public spaces in Alexandria city with different social standard, activities and morphology. A quantitative approach to the physical parameters has demonstrated according to the previous measurements, studies and generated thermal maps, that microclimatic parameters, will influence thermal sensations.

Consequently, the public attendance is negatively affected, in addition to, human activities. This results in a decline in the social cohesion and economic activity. Therefore, a proposal for mitigating the environmental issues using ENVI-Met software was illustrated, accommodating the change in the vegetation type and location, the ground cover and the addition of shading elements in the areas recording high thermal stresses in the current situation simulation. The previous strategies have given improvements comparable to the values available in literature and "PET" values from RayMan. The design of open spaces is crucial for the urban environment and understanding the wide range of effects influencing thermal comfort in these spaces will assist in designing spaces encouraging public use at different seasons of the year, leading to a considerable optimization in their livability.

5 REFERENCES

Abdel-Salam, Hassan. 1996. "Perception of Qualitative Changes in Public Open Spaces: The Case of Alexandria, Egypt." Urban Design International 1(1): 27–40.

Aljawabra, Faisal, and Marialena Nikolopoulou. 2010. "Influence of Hot Arid Climate on the Use of Outdoor Urban Spaces and Thermal Comfort: Do Cultural and Social Backgrounds Matter?" Intelligent Buildings International 2(3): 198–207.

ASHRAE. 2016. Standard 55-2013 User's Manual: ANSI/ASHRAE Standard 55-2013, Thermal Environmental Conditions for Human Occupancy.

Attia, Sahar. 2011. "Rethinking Public Space in Cairo : The Appropriated Tahrir Square." Trialog 108(1): 10–15.

Blazejczyk, Krzysztof et al. 2012. "Comparison of UTCI to Selected Thermal Indices." International Journal of Biometeorology 56(3): 515–35.

Chen, Hong, Ryozo Ooka, Hong Huang, and Takashi Tsuchiya. 2009. "Study on Mitigation Measures for Outdoor Thermal Environment on Present Urban Blocks in Tokyo Using Coupled Simulation." Building and Environment 44(11): 2290–99. http://dx.doi.org/10.1016/j.buildenv.2009.03.012.

Cheung, Pui Kwan, and C. Y. Jim. 2019. "Improved Assessment of Outdoor Thermal Comfort: 1-Hour Acceptable Temperature Range." Building and Environment 151(November 2018): 303–17. https://doi.org/10.1016/j.buildenv.2019.01.057.

Coccolo, Silvia, Jérôme Kämpf, Jean Louis Scartezzini, and David Pearlmutter. 2016. "Outdoor Human Comfort and Thermal Stress: A Comprehensive Review on Models and Standards." Urban Climate 18: 33–57. http://dx.doi.org/10.1016/j.uclim.2016.08.004.

Elgizawy, E 2017. "The Modular Green Living Wall System as an Approach for Environmental Performance Improvement." (Dec.).

Evola, G. et al. 2017. "UHI Effects and Strategies to Improve Outdoor Thermal Comfort in Dense and Old Neighbourhoods." Energy Procedia 134: 692–701. https://doi.org/10.1016/j.egypro.2017.09.589.

Gehl, Jan. 2010. Cities for people Cities for People. ed. Richard Rogers. Copenhagen: island press.

Giannopoulou, K et al. 2011. "On the Characteristics of the Summer Urban Heat Island in Athens, Greece." Sustainable Cities and Society 1: 16–28.

Harlan, Sharon L., and Darren M. Ruddell. 2011. "Climate Change and Health in Cities: Impacts of Heat and Air Pollution and Potential Co-Benefits from Mitigation and Adaptation." Current Opinion in Environmental Sustainability 3(3): 126–34.

Kolokotroni, Maria, and Renganathan Giridharan. 2008. "Urban Heat Island Intensity in London: An Investigation of the Impact of Physical Characteristics on Changes in Outdoor Air Temperature during Summer." Solar Energy 82(11): 986–98. http://dx.doi.org/10.1016/j.solener.2008.05.004.

Koohsari, Mohammad Javad et al. 2015. "Public Open Space, Physical Activity, Urban Design and Public Health: Concepts, Methods and Research Agenda." Health and Place 33: 75–82. http://dx.doi.org/10.1016/j.healthplace.2015.02.009.

Kropf, K. S. 2001. "Conceptions of Change in the Built Environment." Urban Morphology 5(1): 29–42.

Lai, Dayi et al. 2014. "Outdoor Space Quality: A Field Study in an Urban Residential Community in Central China." Energy and Buildings 68(PART B): 713–20. http://dx.doi.org/10.1016/j.enbuild.2013.02.051.

Matzarakis, a, and F Rutz. 2006. "RayMan : A tool for research and education in applied climatology." Physics: 161–168.

Mehan, Asma. 2016. "Investigating the Role of Historical Public Squares on Promotion of Citizens' Quality of Life." Procedia Engineering 161: 1768–73.

Nikolopoulou, Marialena, and Koen Steemers. 2003. "Thermal Comfort and Psychological Adaptation as a Guide for Designing Urban Spaces." Energy and Buildings 35(1): 95–101.

O'Malley, Christopher, Poorang Piroozfar, Eric R.P. Farr, and Francesco Pomponi. 2015. "Urban Heat Island (UHI) Mitigating Strategies: A Case-Based Comparative Analysis." Sustainable Cities and Society 19: 222–35.

Peng, You, Tao Feng, and Harry Timmermans. 2019. "A Path Analysis of Outdoor Comfort in Urban Public Spaces." Building and Environment 148(August 2018): 459–67.

Salata, Ferdinando et al. 2017. "Relating Microclimate, Human Thermal Comfort and Health during Heat Waves: An Analysis of Heat Island Mitigation Strategies through a Case Study in an Urban Outdoor Environment." Sustainable Cities and Society 30: 79–96.

Santamouris, M. et al. 2001. "On the Impact of Urban Climate on the Energy Consuption of Building." Solar Energy 70(3): 201–16.

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