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Article

Adapting Restorative Urban Design, for Open Spaces Towards, Thermal Heat Island, Reaching Human Mental Health and Well-Being, Case Study: Qaitbay Citadel Plaza, Alexandria, Egypt

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Abstract: Nowadays rapidly evolving urban landscape. These challenges increasingly impact residents' mental health and well-being. Overcrowding, noise and air pollution, long commutes, the size of the built environment, landscape and green areas, and the variety of ground surface materials affect outdoor thermal comfort in hot climates to reach mental health and well-being. These public spaces are dealing with the issue of an expanding urban heat island, which affects how users behave. This paper aims to support restorative urban design in Alexandria, Egypt, to reach users thermal comfort, mental health and well-being at the forefront of public spaces. To attain human mental health and well-being in public spaces. Several studies have been done. Such as: Bowling Questionnaire methodology on about 92 participants to assess user perceptions of Qaitbay citadel plaza according to Gehl's theory. And simulated scenarios to measure material effect on users' thermal comfort in the plaza using ENVI-met 4.0 program. As the questionnaire found that: 30% rated accessibility as "poor," and only 75% felt almost unsafe in the area. Thermal discomfort was prevalent, with 40% reporting the temperature as "uncomfortable," 63% finding shaded areas inadequate, and 75% attributing discomfort to heat-retaining surface materials. And mitigate urban heat island phenomena. Through the use of different paving material mitigation strategies, green spaces, and the landscape through different scenarios, till reaching the best scenario which decrease the minimum temperature 2.06 °C and the maximum temperature 3.59 °C for users' thermal comfort and wellbeing inside the space reaching to a restorative urban public space.

Keywords: El Anfoushy Neighborhood; Gehl's Theory; Mental Health & wellbeing; Qaitbay citadel plaza; Restorative Urban Design; Urban Public Spaces; Thermal Comfort; Urban Heat Island

1. Introduction

Recently, cities are facing huge population growth, and an increase in urban fabrics (Johnson et al., 2012). Over the past few decades, urban areas have regularly expanded their boundaries. Such as: lengthy commutes, dense building materials, more constructive materials, asphalt pavements, and the reduction of green areas, and hard impermeable layers (Kovats, 2008; Santamouris, M., 2014). This had a huge impact on rising levels of pollution, solar radiation, global warming and increase in urban heat island (UHI) (Heaviside, C., Cai, X-M., and Vardoulakis, S., 2015; Wilkinson, P., Smith, K.R.and Davies, M., et al., 2009). All these factors affect the mental health and well-being of urban public space users (Vardoulakis, S., Dimitroulopoulou, S. and Thornes, J.E., et al., 2015). In general, both the nature and

human mental health and well-being are negatively impacted by changes in the microclimate (Raven, R., et al., 2014).

Public spaces in urban areas are mainly affected by heat waves (Wilkinson, 2009).Users frequently visit urban public spaces to rest area and leisure specially in summer days (Barton, 2000). The majority of people spend their time specially on summer day outside in hot, dry regions, particularly in Alexandria, Egypt (Elwan, 2017). This supports the need to improve the outdoor thermal comfort environment and user comfort for a better mental health and wellbeing (Ali-Toudert, 2007; Taha, 1997). Qaitbay Citadel Plaza (the case study) is considered a historical touristic space surrounded by historical recreational buildings and space. The space faces many problems that affect users' comfort such as; the use of unsuitable materials for flooring and pavements, no shadings, high humidity during the presence of the sea, and no vegetation that affect both users mental health and thermal comfort (Al-Hadid, 2023). Thus, restorative urban design should be adapted to emphasize the importance of green spaces and natural elements in urban design that help to improve users' thermal comfort (Klemm, 2017; Van den Berg, 2010). Restorative urban design help to promote social interaction and community engagement (Kessler, R. C., Andrews, G. and Colpe, L. J., et al., 2002) supports and enhances the physical, mental, and emotional well-being of residents, while also promoting sustainability and resilience of the space (Beatley, 2016).

This paper concerns the thermal comfort and human mental health and wellbeing in the case study "Qaitbay Citadel Plaza" area in Alexandria city. By studying the plaza before and after implementing restorative urban design strategies. These strategies combined the principles of public space design focused on enhancing mental health and wellbeing with urban heat island (UHI) mitigation measures. Through introducing the importance of cooling materials, vegetation, shading, and water features. These modifications aimed to decrease surface temperatures and improve user comfort, thus aligning environmental and social objectives for sustainable urban public spaces.

1.1. Research Questions

- What are the criteria that should be considered to reach users mental health and wellbeing in the urban public spaces?
- How users' thermal comfort affects users' mental health and wellbeing at Qaitbay citadel plaza?
- Did the questionnaire and the simulation program help to reach thermal comfort and users mental health and wellbeing at Qaitbay citadel plaza?

1.2. Methodology

This paper collects some data in term of literature review to help to understand and applicate it on the case study (Qaitbay citadel plaza):

First: The literature review explores the principles for a successful urban public space for users' mental health and wellbeing, urban heat island (UHI) effect mitigating, restorative urban design principles, and their impact on thermal comfort and mental wellbeing.

Second: Analyze the case study, the Qaitbay Citadel Plaza in Alexandria in term of the literature review through different methods (Figure 1):

1. **Researcher Site visit:** Researcher made several visits to the site and recognized users' activities in the public space and took photos.
2. **User Feedback and Surveys**: A Bowling Questionnaire using an online survey platform "Microsoft Forms" with 92 participants, to assess user point of view regarding comfort, accessibility, safety, environmental quality, material thermal comfort.
3. **Simulations with ENVI-met Software**: The effects of different surface materials, vegetation, and shading on microclimate conditions to analyze the thermal performance inside the space.
4. **Proposed Scenarios**: Multiple scenarios were proposed and analyzed. These scenarios mitigate UHI measures, through using cool paving materials, green spaces, and water features.

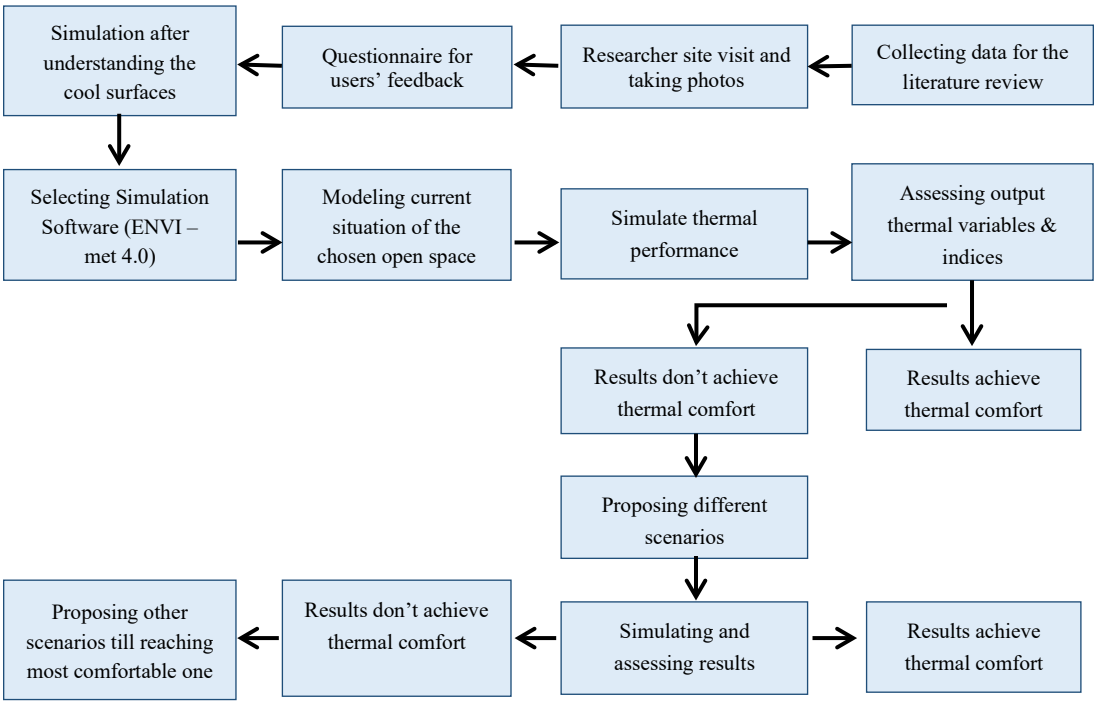

Figure 1. The adapted Methodology for this paper. Source: Researchers.

2. Literature Review:

2.1. Public Space

The Public space consists of three main elements: space, buildings, and life. Space is the physical accessible area for all, buildings considered as structure and shelter, while life refers to social interactions and activities happens in the space. All these elements help to create a vibrant urban environment to facilitate gathering, and community engagement (Figure 2) (Gehl, J., 2011). Public spaces are one of the main components of urban environments that improved according to society needs. As it plays an important role in facilitating community engagement, Arts and cultural expression, and economic activity (Gehl, J., 2011). Public spaces have gone through several studies and theories to reach the critical frameworks for public space to obligate social engagement, and sustainable development. This study examines prominent theories and conceptual frameworks to understand the urban public space criteria to reach users comfort and wellbeing.

Figure 2. Gehl's definition for a public space, Source: (Gehl, J., 2011).

2.1.1. Gehl's Theory of Public Space

The relationship between urban design and mental health has also been explored through the lens of Gehl's Theory of Public Space Design, which emphasizes the importance of creating lively, safe, healthy, attractive and sustainable urban environment (Figure 3) according to (Gehl, 2010), public spaces should encourage sociability and interaction, offering comfort and safety for all users. These spaces are not only essential for social cohesion but also for promoting physical activity and reducing feelings of isolation; key factors in maintaining good mental health. Gehl's work highlights the importance of designing public spaces that are inviting, aesthetically pleasing, and conducive to well-being. Reaching to Gehl's theory; by examining the importance of different principles: Safe, secure, climate, enhancing sensory, stand and stay, views, play and exercise, seating and talk scape that is explained clearly in (Figure 3) (Gehl, 2010). The researcher created the questionnaire depending on these aspects to measure user comfort, mental

health and wellbeing inside Qaitbay citadel plaza as shown in the case study point.

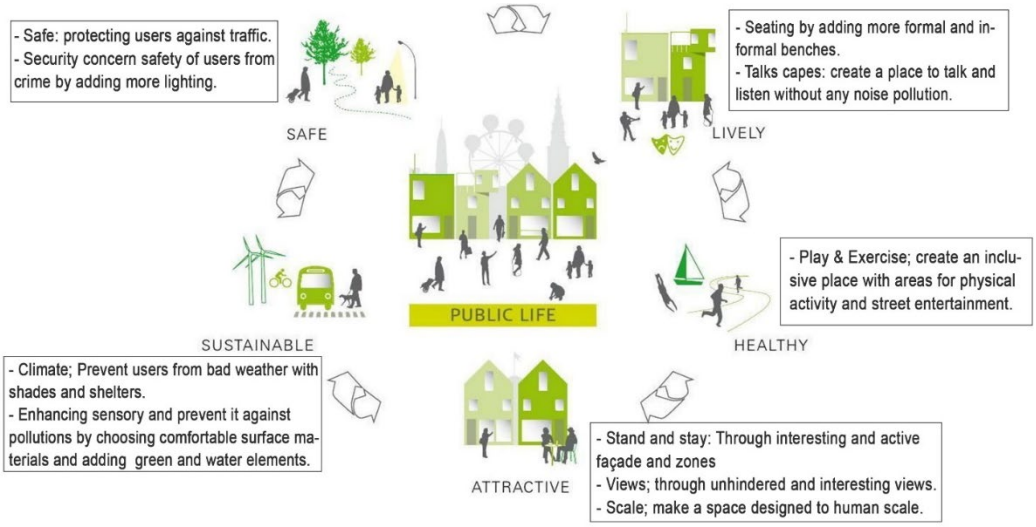

Figure 3. Gehl's Theory of public space design, Source: (Gehl, 2010), Edited by: Researchers.

2.1.2. Public Space Effect on Mental Health and Wellbeing

Successful urban designed public spaces help to improve mental health and well-being by enhancing social interaction, physical activity, and restorative experiences. As, well-designed public spaces offer opportunities for relaxation and recreation, that reduces stress, anxiety, and depression. Access to green spaces, in particular, has been shown to improve mood and cognitive functioning, offering psychological benefits by allowing individuals to connect with nature (Kaplan, R. and Kaplan, S., 1989). Public spaces foster social cohesion by creating a space for people with different backgrounds and ages to interact and engage. This social cohesion in public spaces decreases feelings of loneliness and isolation (Gehl, 2010). Beside improving users' physical activities, such as walking, jogging, or playing, which has a positive impact on both physical and mental health.

2.2. Restorative Urban Design

To reach a restorative city, you must consider both the big picture (such as the transportation infrastructure) and the smaller picture, which includes daily 'episodic' activities, such as life on the bus, life in the plaza and life in the café. Through the restorative city Framework (Figure 4), the idea of an "inclusive city" is combined with six additional typologies (green, blue, sensory, neighborly, active and playable city). Where the green city means bringing nature into the heart of the city. Blue city (maximizing access to water settings for well-being. Sensory city immersing all five senses. the neighborly city is supporting social cohesion. Active city supports cognitive and emotional users' wellbeing through mobility. Finaly the playable city provides chances for play and creativity for all ages (McCAY, 2019). Thus, restorative urban design improves mental health, social interaction, and comfort through green infrastructure and natural elements (McCAY, 2019). Where green, natural elements and permeable surfaces are also features that mitigate urban heat island effects as reduces surfaces exposed to temperatures (Klemm W. and Lenzholzer S., 2017).

Figure 4. The Restorative City Principles, Source: (McCAY, 2019).

2.2.1. Concept of Urban Heat Island

The UHI phenomenon arises when cities replace the natural land cover with densely packed areas of heat-absorbing buildings, pavements, and other surfaces. It's a kind of air pollution that fuels global warming, as well in contrast to the nearby suburban and rural areas. The temperature of urban regions, such city centers, is elevated by (UHI) urban heat island (Oke I. D., 2012). One of the biggest anthropogenic changes to Earth's ecosystems is the Urban Heat Island (UHI), phenomena where temperatures are higher in urban areas than they are in non-urban ones (D. Zhou, 2014).The primary data sources for surface UHI investigations are air temperatures and land surface temperature (LST), which are retrieved from thermal infrared remote sensing data. UHI is the term used to describe the difference between the atmosphere (AT) inside a city and the (AT) outside of it (D. Zhou, 2014). The two main methods for analyzing the UHI phenomenon are LST measurements derived from thermal infrared (TIR) remote sensing data or conventional weather station automated temperature readings (A. Tzavali, 2015). One of the challenges for the future is reducing the predicted increase in winter temperatures as well as the frequency of extremely hot days and nights during the summer (T. Stocker, 2013).

Surface urban heat islands (SUHI) and atmospheric urban heat islands (AUHI) are the two different categories of UHI. The primary traits of both types of heat islands are enumerated in (Table 1) (Basics, 2011).

Table 1. The difference between (AUHI) and (SUHI), Source: (Riham Nady Faragallah and Riham A. Ragheb, 2022).

Types	(AUHI)	(SUHI)
Temporal variation	- High intensity during the day in winter and at night.	- High intensity during the day in summer and at night.
Intensity of UHI	Less variation - Day (–1 to 3 °C) - Night (7 to 12 °C)	Temporal variation - Day (10 to 15 °C) - Night (5 to 10 °C)
Methods	Direct measurement: - Fixed weather stations & Mobile travel	Indirect measurement: - Remote sensing
Description	Isotherm map - Temperature graph	Thermal image

Warmer air in urban areas relative to colder air in the surrounding rural areas. Researchers have often divided heat islands into two groups (Figure 5) (A. Tzavali, 2015; Gong, 2013):

- The canopy layer urban heat island (CUHI): A layer extending upward from ground level to the ground mean height of buildings.
- The boundary layer urban heat island (BUHI): A layer of air up to 2000 meters height above the canopy layer.

The canopy layer is a local neighborhood-scale phenomenon (Oke T., 1976). The area between buildings and the roofs of the buildings forms the urban canopy layer (Ridha, 2017). The near-surface layer is cooler than the urban canopy layer. This could lead to the development of urban heat islands. Urban expansion results in heat islands (HIs) because various structures, streets, pavements, and surface materials absorb heat during the day and release it at night, raising the temperature above surrounding locations. The term "unplanned urbanization" (UHI) refers to a trend that causes the urban surface and atmosphere to change and become hotter (Voogt JA and Oke TR., 2003). The properties of the urban and rural surfaces are affected by the timing of the peak, the weather conditions, and the season (EPA, 2011). Urban heat islands (UHIs) are created when cities experience rapid urbanization, unexpected climate changes, and rising air and surface temperatures (JA., 2004). The urban heat island is affected by weather and climate. The quantity of clear sky and gentle breezes increases. Lowering heat convection and allowing solar energy to reach the earth. In addition, geography and climate are influenced by geographic location. Large watersheds, for instance, lower the temperature above the atmosphere, and mountains, if they exist, may block the winds (EPA, 2011).

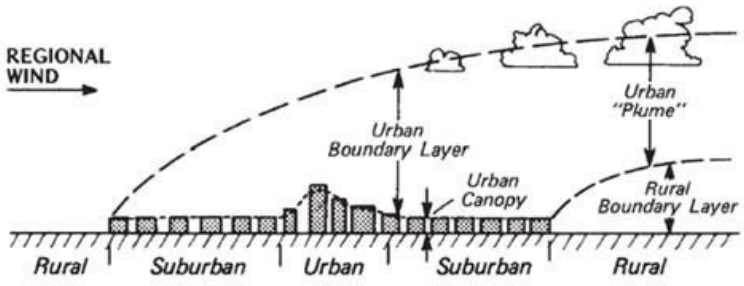

Figure 5. Urban Canopy & Urban Boundary Layers, Source: (Ridha, 2017).

While taking in consideration, anthropogenic activities that is produced by human activity and that come from several sources, such as people's energy use, buildings, cars, and industrial operations. It is determined by totaling the energy used for running appliances, moving vehicles, and doing industrial operations. It can originate from a variety of sources. Depending on urban activity and infrastructure, different amounts of heat are created by human activity and infrastructure; more energy intensive structures and modes of transportation produce more heat and increase (UHI) (EPA, 2011).

2.2.2. Effect of Surface Material on Urban Heat Island

Besides the impact on land surface due to changes in land use affects urban heat islands. Materials used in rural areas, concrete, and asphalt have significantly different thermal characteristics and surface radiation characteristics (Albedo and emissivity) (M. N. Hamoodi, 2019). The lack of vegetation in urban areas further affects the energy balance because it reduces the surface's natural cooling ability through Evapotranspiration. The size and spacing of buildings within a city, and urban geometry also affect wind flow, energy absorption, and emission (EPA, 2011). The Use of cooling material pavement that are permeable, reflective, and have a high Albedo enhances the microclimate (vidsen D and Green J., 2019). Cooling pavement reduce surface temperature as it is characterized by; low heat conductivity, low heat capacity, high solar reflectance, and high permeability characterize cool surface materials (K., Yenneti, 2020). These reflective surfaces also provide a negative radiative force that directly offsets the effects of rising greenhouse gas concentrations (M., Hendel, 2016).

There are several types of cooling materials (Figure 6), such as:

a. Permeable pavements: made of burned clay bricks, grass, or concrete layers that allow water vapor and air to permeate the pavement's spaces. For example; Porous asphalt, pervious concrete, permeable pavers, grid pavements, and interlocking pavers. These pavements lower the temperature via evaporative cooling when they are wet. (Ferguson B, 2005).
b. Reflective pavements: Designed to reduce surface temperatures during the day by reflecting solar radiation. It is effective especially in dry regions with high sun exposure. For example:

The highly reflecting grey cement concrete has an albedo that is 0.18–0.39 less than that of the most reflective white cement concrete (Yinghong., 2015)

c. Colored pavement: Through blending color pigments and sealants with asphalt. This provides the surface with a brighter and more reflecting appearance. They are frequently utilized for cycling routes, pathways, and driveways (Bek MA, 2018).

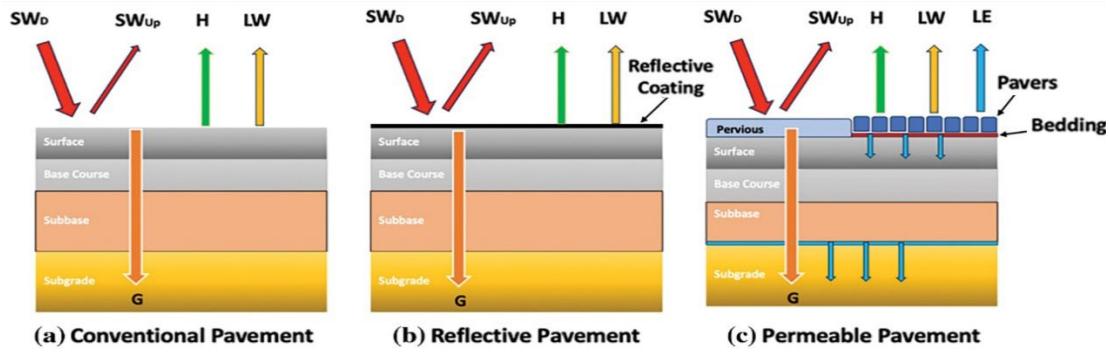

Figure 6. Pavement mechanism works, Source: (Wang C, W. Z., 2021).

3. Case Study of Public Space

3.1. Qaitbay Citadel Plaza at El Anfoushy Neighborhood

Alexandria is a Mediterranean city with a history dating back more than 2,000 years. It is Egypt's second-largest city, behind Cairo. It was previously home to the famed Pharos Lighthouse, one of the ancient world's seven wonders. Alexander the Great founded it in 331 BC (Mohamed A. F., 2023). El Anfoushy Neighborhood considered a historic neighborhood located in the Eastern Harbor at the western part of Alexandria, Egypt. It's nestled between the Mediterranean Sea to the north and the vibrant city center to the south of Alexandria at Latitude 31° 12' 33.192"N and Longitude 29° 52' 41.016"E (Latlong.com Anfoushy, Alexandria, Egypt 2023) (Figure 8). As of 2023, Alexandria was home to 3,811,516 individuals (Statistics Egypt 2023). This neighborhood is located on the ancient Pharos peninsula and is considered one of the oldest neighborhoods in the city. El Anfoushy is a densely populated residential area, which has a rare number of smaller public gardens and open areas where residents can enjoy some greenery. It is considered a place where residents can enjoy the sea breeze and open views. Despite all of this, the public spaces in El Anfoushy neighborhood aren't well designed for human use and comfort.

Figure 7. Location of El Anfoushy neighborhood, Source: Google Maps.

Figure 8. Qaitbay Plaza at El Anfoushy neighborhood, Source: Google Maps.

Qaitbay Plaza is considered as one of the most prominent landmarks in El-Anfoushy neighborhood, where Qaitbay Citadel is found which is considered as Alexandria's maritime history and ancient grandeur. It is located by the end of the northern waterfront of Alexandria at “kayetbay” in front of the Citadel of Qaitbay reaching Qaitbay square (Figure 9), which is considered a main historical commercial public space surrounded by leisure buildings. Some proposed design recommendations were implemented at Qaitbay Plaza in El-Anfoushy neighborhood to enhance the public space for users’ thermal comfort and reach their mental health and well-being.

Figure 9. Qaitbay Plaza at El Anfoushy neighborhood, Source: Researcher.

3.2. Climate Analysis at El Anfoushy Neighborhood

El Anfoushy, Alexandria, Egypt, experiences a hot, dry summers and mild, wet winters which is considered as Mediterranean climate (Mohamed A., 2023). Range of summer temperature between 30 °C to 34 °C (86°F to 93°F), while winter temperatures between 9 °C to 18 °C (48°F to 64°F) (Figure 10). The place experience high humidity levels, especially in summer, averaging between 60% and 80% (Egypt. S, 2023). The heat and humidity lead to discomfort of users specially during the heat waves caused by climate change (Programme, 2022). The urban heat island effect cause discomfort especially for residents in densely populated areas like El Anfoushy (Studies., 2021). The frequency increase in intensity of heat waves can lead to heat-related illnesses, dehydration, and fatigue, negatively impacting mental well-being.

Heat waves disrupt daily routines, limit outdoor activities, and contribute to feelings of discomfort and irritability. The absence of natural and green landscapes due to urbanization, lead to increase in UHI, causing human stress and discomfort. The mental health impacts of climate change in El Anfoushy requires strategies that promote resilience, adaptation to improve users’ mental health.

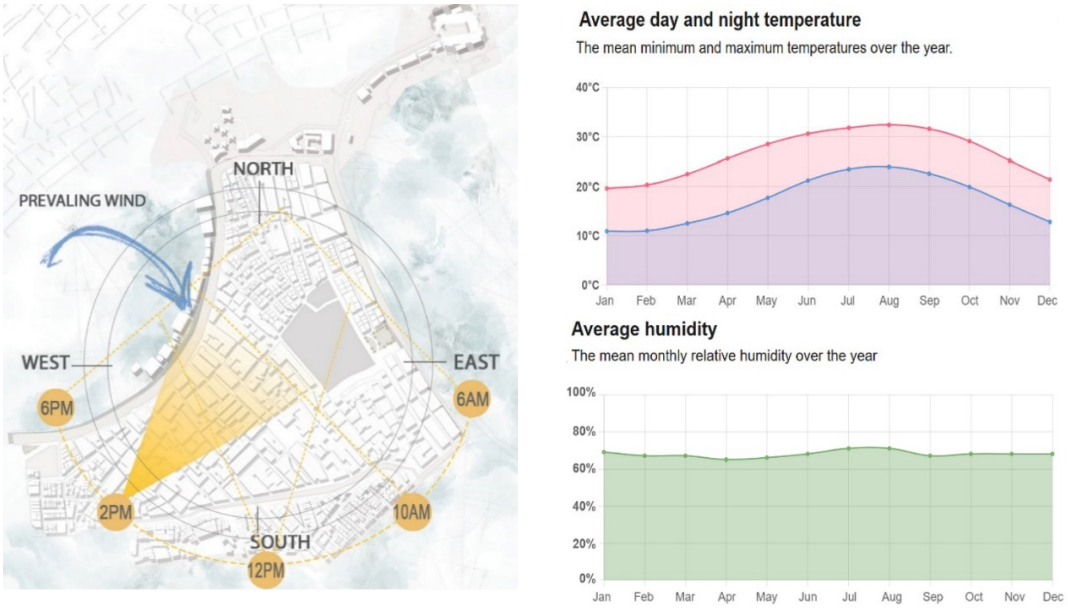

Figure 10. El Anfoushy Climate Analysis, temperature and humidity of Alexandria, Egypt, Source: 3d max modeling program edited by researchers & (Egypt. S, 2023).

3.3. Building Condition & Heights at Qaitbay Citadel Plaza

There is leisure urban building surrounding the public space which ranges in height from 5 to 24 meters (Figure 10). Besides the condition of the building surrounding Qaitbay citadel plaza varies between Average to Very good (Figures 11 and 12).

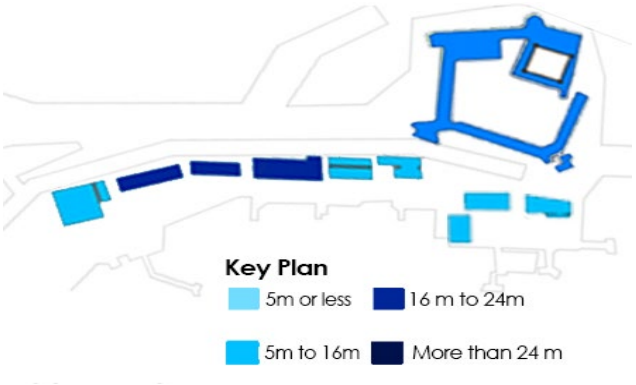

Figure 11. The buildings heights surrounding Qaitbay Plaza, Source: AutoCAD tracing modified by researchers.

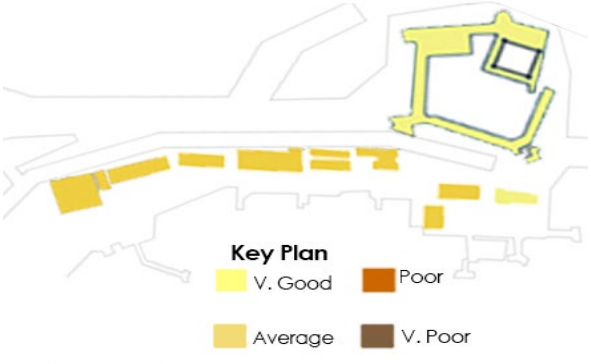

Figure 12. The buildings conditions surrounding Qaitbay Plaza, Source: AutoCAD tracing modified by

researchers.

3.4. Materials used at Qaitbay Citadel Plaza

The area is surrounded by traditional and historical buildings that vary in terms of their materials, colors, and textures with large windows and glazed facades that allow plenty of natural light and views and solid walls, less transparent facades & different materials adding unique appearance (Figure 13).

Figure 13. Facades and Frontages surrounding Qaitbay Plaza, Source: Taken by the researchers.

The building structure of the buildings surrounding the public space is made of engineered materials (concrete and glass) with sharp edges and a bearing wall at Qaitbay citadel (Figure 14) as the almost blocked buildings increase the temperature, due to the presence of more absorbing heat material. Most of the surfaces in the space; are characterized by dominant surfaces as dark surfaces and less permeable surfaces. The space has no cooling elements such as vegetation and trees that could be used as shading and shelters, leading to thermal discomfort on hot summer days due to the increase in temperature directly on the dark surfaces with no natural elements causing absorption of heat and thermal discomfort (Figure 15). Besides, the air conditioning system used by the surrounding buildings causes an extra load of heat on urban public space (Bek MA, 2018).

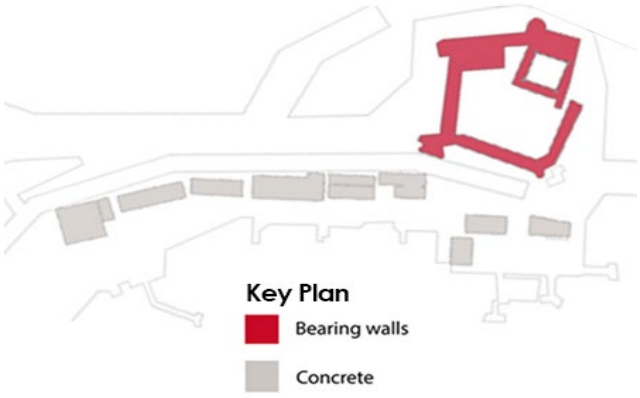

Figure 14. Structure material of the buildings surrounding Qaitbay plaza, Source: AutoCAD tracing modified by researchers.

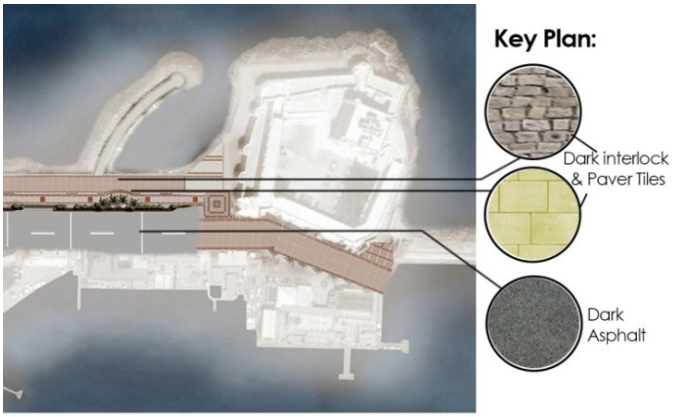

Figure 15. The Surface covering of Qaitbay plaza, Source: AutoCAD tracing modified by researchers.

3.5. User Survey & Quantitative Survey at Qaitbay Citadel Plaza

The number of people using the plaza at various time intervals reveals those warm conditions, beside the presence of 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 12:00 PM which recorded high temperatures in addition to elevated relative humidity. Moreover, the cultural, social and religious aspects of the country showed the absence of females at late hours of the night while, as shown in the following diagram user's demography at the plaza according to the researchers' observation (Figure 16).

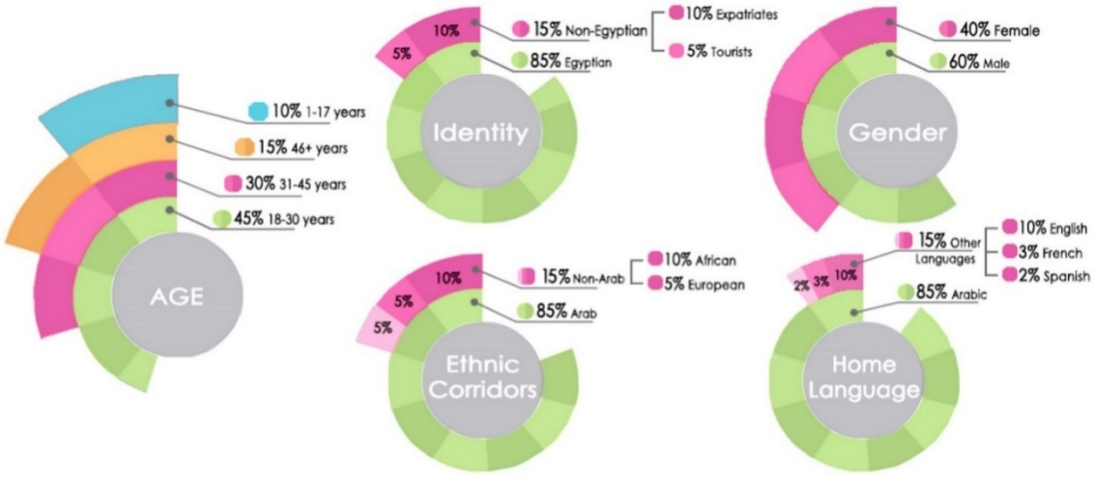

Figure 16. Qaitbay Plaza demography according to researchers' observation to the site (age, gender, identity, ethnic corridor, home language), Source: Researchers.

Researchers observed users' activity in the plaza at different times of the day and according to the questionnaire of the plaza (Figure 17). there was more concern about resting areas, since people choose to sit somewhere rather than a pathway which is less likely to be chosen, 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.

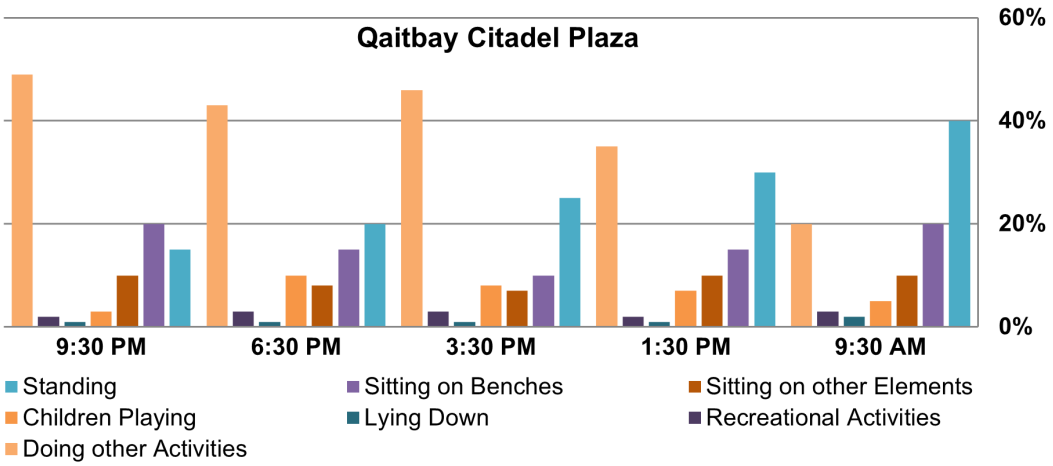

Figure 17. Users activities at Qaitbay Plaza by 9.30 am, 1.30 pm, 3.30 pm, 6.30 pm and 9:30 pm, Source: Researchers.

3.6. Qualitative Survey at Qaitbay Citadel Plaza

A Bowling questionnaire was done at Qaitbay Plaza with 20 questions. Using an online survey platform "Microsoft Forms" to facilitate the distribution and completion of the questionnaire. This questionnaire done with measurements according to Gehl's theory to measure users' satisfaction (comfort, accessibility, safety, sensory, human scale, and environmental quality) and users' thermal comfort (surface materials, vegetations and shadings) in the space. The percentage was measured according to 92 users' point of view percentage between (excellent – yes), (neutral – not sure), (poor – no) and the results percentage either decrease and increase according to number of users answers. The results are documented in form of (Table 2) and graph as shown in (Figure 18).

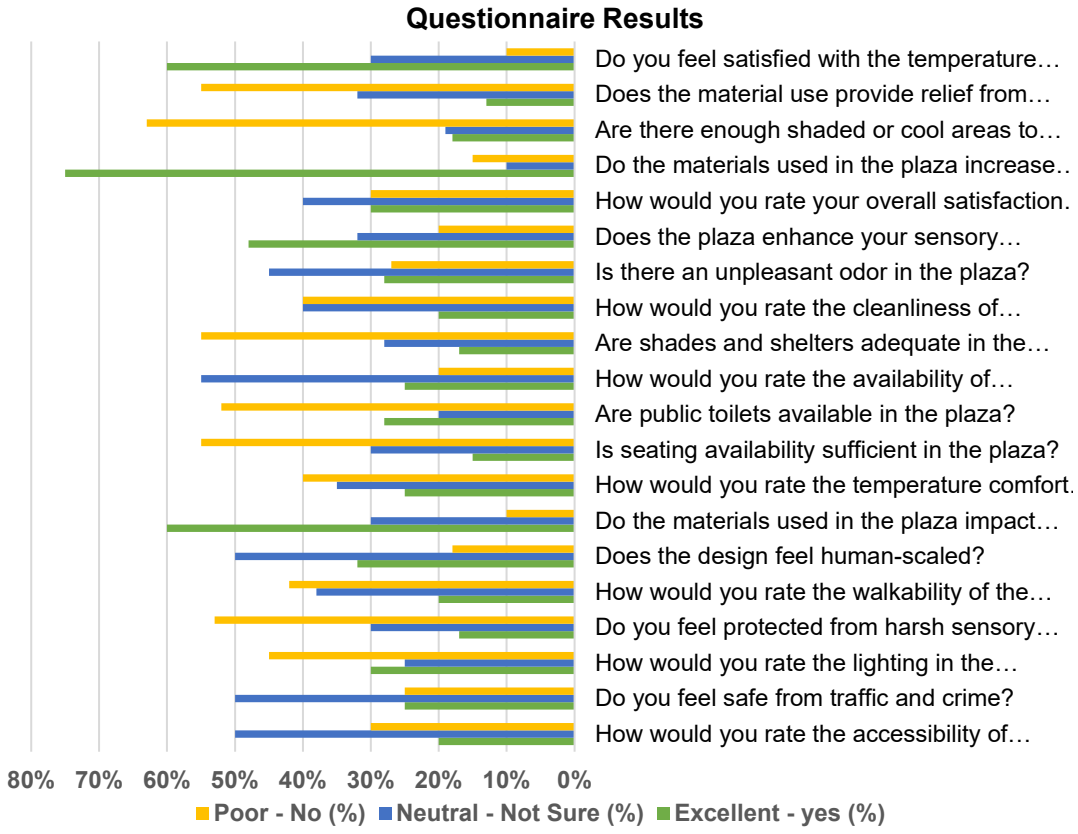

Figure 18. Questionnaire results percentage according to users' survey, Source: Researchers.

Table 2. Results from Microsoft Forms bowling questionnaire, Source: Researchers.

Question Title	Excellent - yes (%)	Neutral – not sure (%)	Poor- No (%)
How would you rate the accessibility of Qaitbay Plaza?	20%	50%	30%
Do you feel safe from traffic and crime?	25%	50%	25%
How would you rate the lighting in the evening/night?	30%	25%	45%
Do you feel protected from harsh sensory elements (sun, wind, rain)?	17%	30%	53%
How would you rate the walkability of the plaza?	20%	38%	42%
Does the design feel human-scaled?	32%	50%	18%
Do the materials used in the plaza impact your comfort (e.g., heat-retaining surfaces)?	60%	30%	10%
How would you rate the temperature comfort during your visit?	25%	35%	40%
Is seating availability sufficient in the plaza?	15%	30%	55%
Are public toilets available in the plaza?	28%	20%	52%
How would you rate the availability of parking facilities?	25%	55%	20%
Are shades and shelters adequate in the plaza?	17%	28%	55%
How would you rate the cleanliness of Qaitbay Plaza?	20%	40%	40%
Is there an unpleasant odor in the plaza?	28%	45%	27%
Does the plaza enhance your sensory experience?	48%	32%	20%
How would you rate your overall satisfaction with Qaitbay Plaza?	30%	40%	30%
Do the materials used in the plaza increase heat discomfort?	75%	10%	15%
Are there enough shaded or cool areas to counteract heat?	18%	19%	63%
Does the material use provide relief from sun/heat?	13%	32%	55%
Do you feel satisfied with the temperature during your visit?	60%	30%	10%

Qualitative survey feedback for Qaitbay Plaza, in El-Anfoushy, Alexandria, Egypt, based on users' feedback (Table 3):

Table 3. show strength, weakness, and potentials according to Qaitbay Questionnaire, Source: Researchers.

Strengths	- Rich historical background at Qaitbay citadel plaza. - View: The public space offers stunning panoramic views of the Mediterranean Sea - Stand & Stay: Users opportunity to explore and experience the local culture in Qaitbay Plaza. - Sensory: It's a perfect place for leisurely walks and relaxation.
Weaknesses	- Heat discomfort: surface material absorbing temperature and heat. - No enough green spaces and vegetations to absorb heat leading people to feel thermal discomfort - The use thermal absorbing materials for buildings. - Lack in shades and shelter, that visitors are almost exposed to harsh weather as sun and rain.

	- Limited Amenities: The place need more seating options, shaded areas, and recreational facilities. - The need of installation of wheelchair ramps, improved pathways, and clear signage to ensure equal access for all visitors. - No public toilets as there are semipublic toilets.
Potentials	- Adding more shading areas, trees, water elements to decrease the surfaces exposed to the sun. - Thermal comfort: Covering the land and surfaces with cooling materials and permeable surfaces to decrease the heat absorption. - Redesign pathways for pedestrian and cycling and add ramps for disabilities to make the plaza more accessible. - Amenities: add more seatings, public toilets and parking options. - Enhance sensory: more landscape, public arts. - Safe and secure: Add more lightings and security cameras. - Shelter and shades: To protect from sun and rain and decrease surfaces exposed to sun. - Enhance green and water elements for leisure experience and as cooling elements on hot weather. - Add some grass, green areas and playground for users to play on and enjoy their time.

3.7. Envi- met simulation for Qaitbay citadel plaza

By using Envi-met to simulate the current situation for Qaitbay citadel plazas and the expected situation after changing the used materials with cooling material and adding some vegetations with different proposals. The analysis of the public space happened in summer July, 2023 by 1:00 pm (considered the highest temperature hour). The simulation hours happened among 12 hrs from 6:00 am to 6:00 pm after the simulation, the analysis results exported using Leonardo on Envi-met. The weather and humidity data (mentioned before) are added to Envi-met program to start measure and simulate the plaza results (Figure 19).

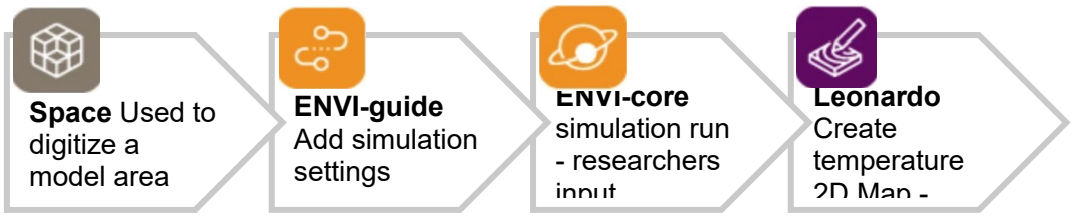

Figure 19. Steps done by researchers using Envi-met program to reach the temperature map, Source: Researchers.

Input some data to Envi-met program such as; location of the site, the heights of the buildings which is between 5 to 24 meters (Table 4) and the materials of the surfaces in the public spaces beside the green spaces in the area (space step). The simulation happened in term of; current situation and Scenario 1, Scenario 2, Scenario 3, and Scenario 4 through changing the surfaces materials and adding some green and blue elements:

a. **The current situation of Qaitbay Plaza:** Consist of the parking area covered with dark asphalt, the pavements covered with dark interlock and paver tiles. At this case the air temperature varies from 21.53 °C to 29.78 °C (Figure 20).
b. **Scenario one for Qaitbay Plaza:** after adding some green elements and water elements the temperature at the public space decreased by 0.26 °C from the minimum temperature and decreased

0.34 °C from the maximum temperature. In this case, the air temperature varies from 21.01 °C to 29.09 °C (Figure 21).

c. **Scenario two for Qaitbay Plaza:** after adding some green elements and water elements changing the material of the surfaces from dark asphalt to colored asphalt and changing the sidewalk material from interlock and paver tiles to brick stones the temperature at the public space decreased 0.59 °C from the minimum temperature and decreased 0.91 °C from the maximum temperature. In this case the air temperature varies from 20.94 °C to 28.87 °C (Figure 22).

d. **Scenario three for Qaitbay Plaza:** after adding some green elements and water elements changing the material of the surfaces from dark asphalt to colored asphalt and changing the sidewalk material from interlock and paver tiles to concrete light color the temperature at the public space decreased by 1.32 °C from the minimum temperature and decreased 2.55 °C from the maximum temperature. In this case, the air temperature varies from 20.21 °C to 27.23 °C (Figure 23).

e. **Scenario four (the most suitable proposal) for Qaitbay plaza:** after adding some green elements and water elements and changing the material of the surfaces from dark asphalt to basalt and changing the sidewalk material from interlock and paver tiles to granite paving stones the temperature at the public space decreased 2.06 °C from the minimum temperature and decreased 3.59 °C from the maximum temperature. At this case the air temperature varies from 19.47 °C to 26.19 °C (Figure 24).

Table 4. The Data Entry for the Simulation Program, Source: Researcher.

Type	Parameter	Value
Location	City	Alexandria, Egypt
	Latitude	31.200 N
	Longitude	29.920 E
Time of Simulation	Day	11 July 2023
	Time	12 hrs from 6:00am till 6:00pm
Weather Condition	Humidity	72 %
	Initial Temperature	From 23 °C to 32 °C
	Average Wind speed	3.65 m/hr.
Buildings	Building Heights	From 5 m to 24 m
	Material Thermal conductivity	1.6
	Cooling Materials	0.64
Road	Road width	23.36 meter
	Side walk width	25.58 meter
	Road Material	Dark Asphalt
	Sidewalk Material	Dark Interlock and Paver tiles
Greening	Grass	2.0

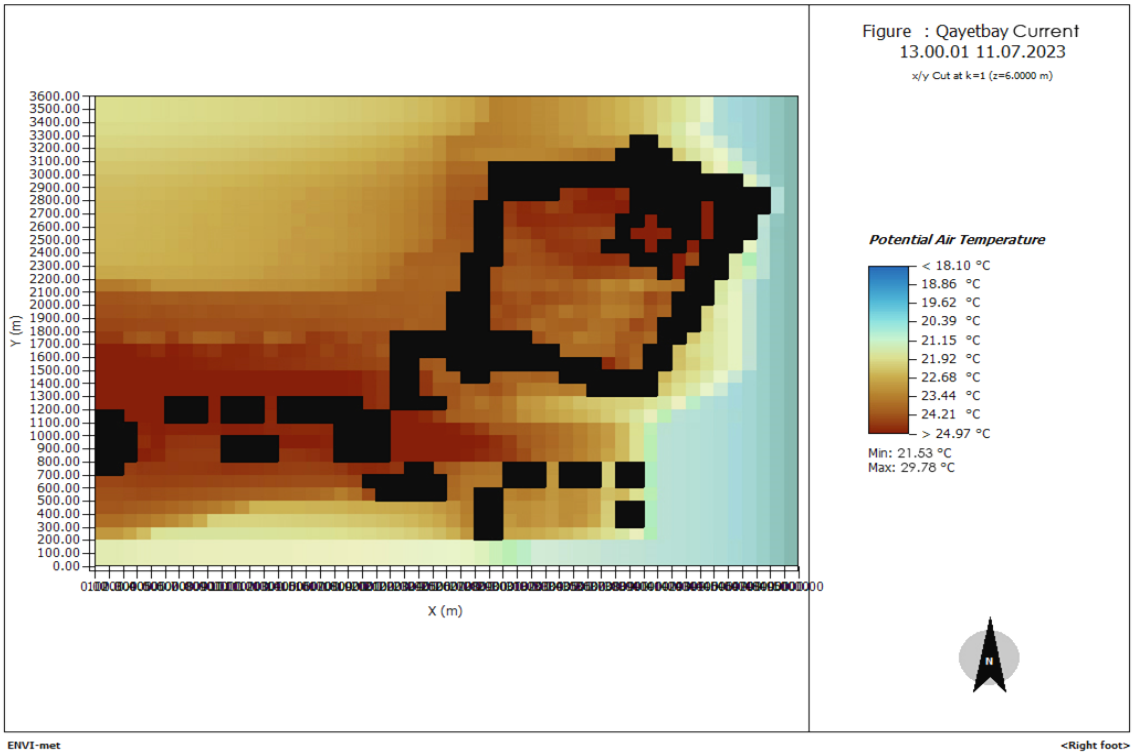

Figure 20. Current situation map of potential air temperature, Source: Envi-met analysis after simulation using LEONARDO.

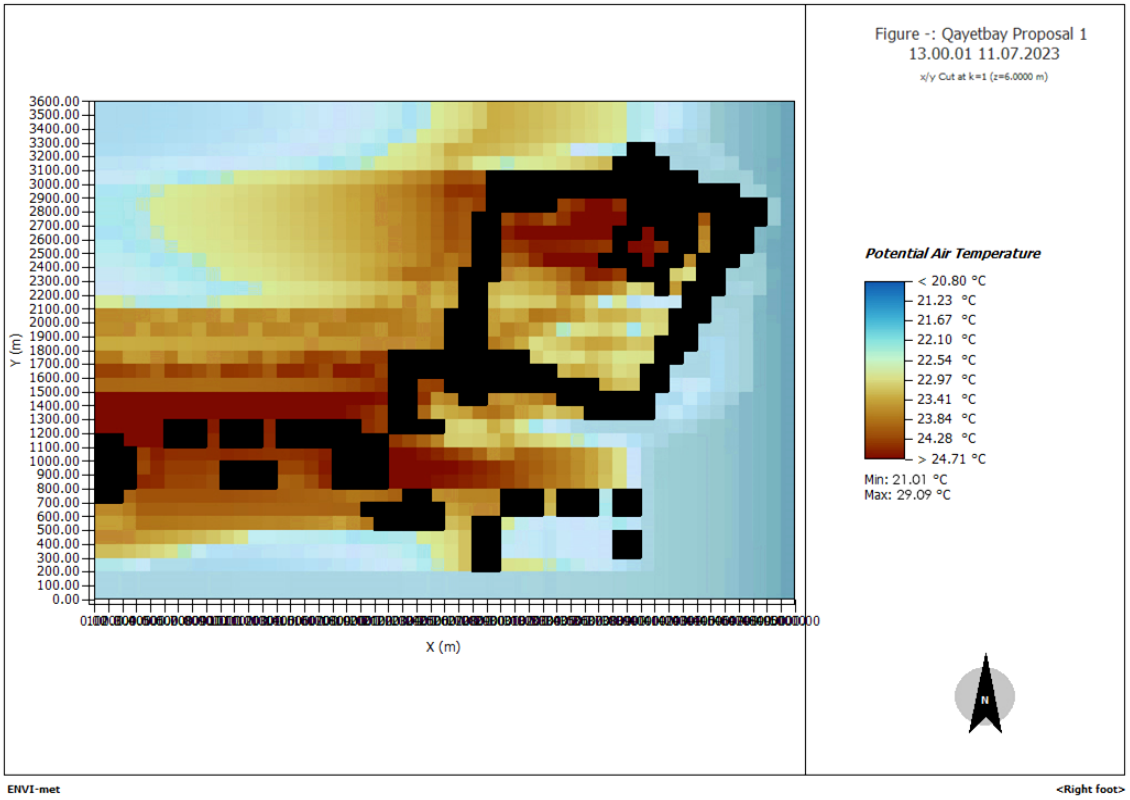

Figure 21. Scenario one map of potential air temperature, Source: Envi-met analysis after simulation using LEONARDO.

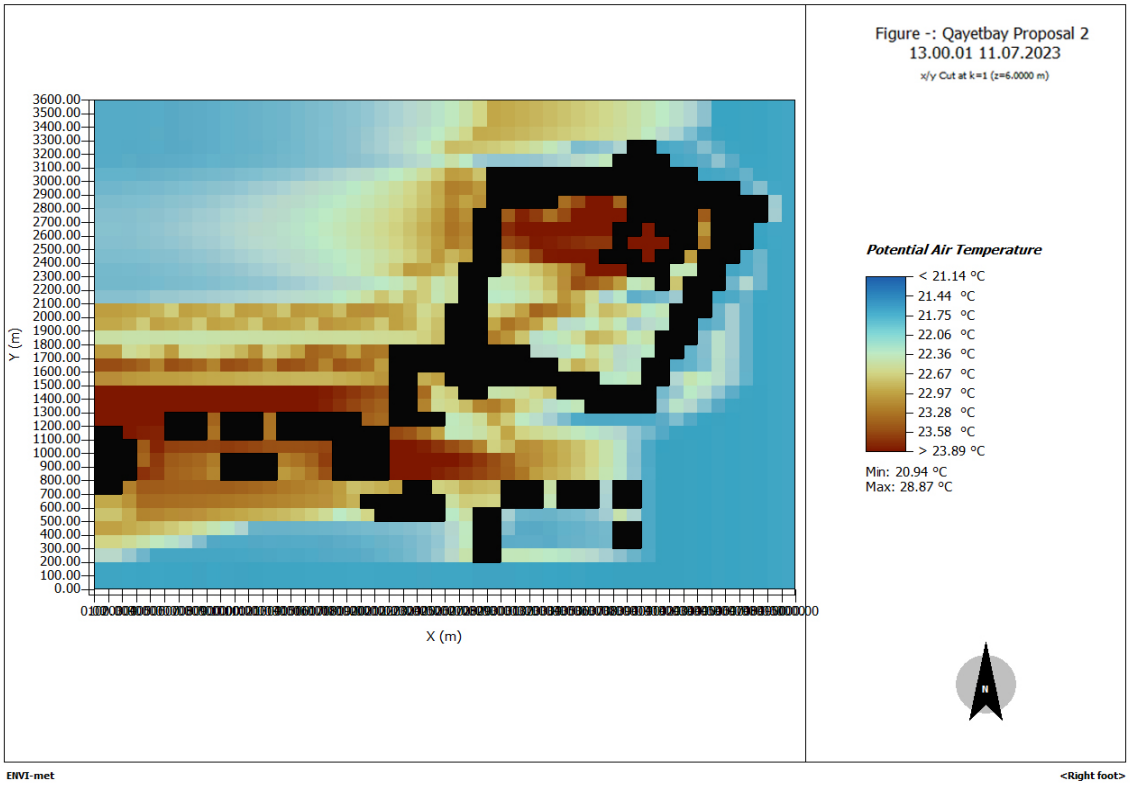

Figure 22. Scenario two map of potential air temperature, Source: Envi-met analysis after simulation using LEONARDO.

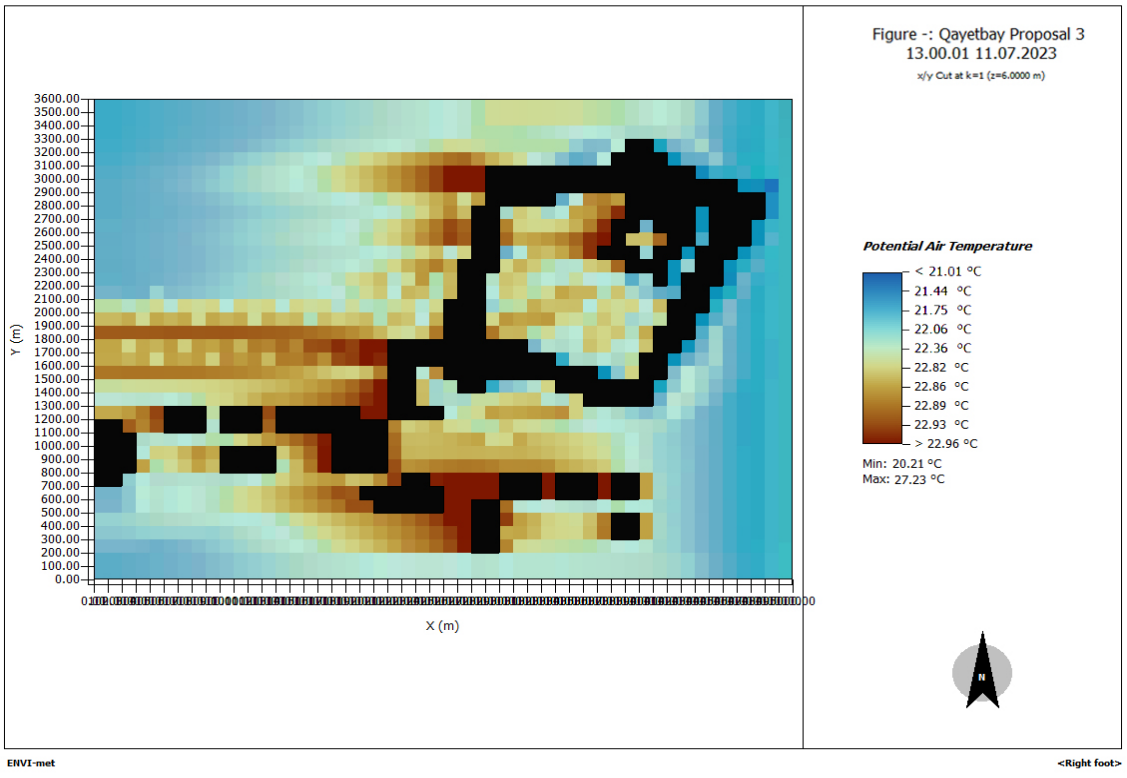

Figure 23. Scenario three map of potential air temperature, Source: Envi-met analysis after simulation using LEONARDO.

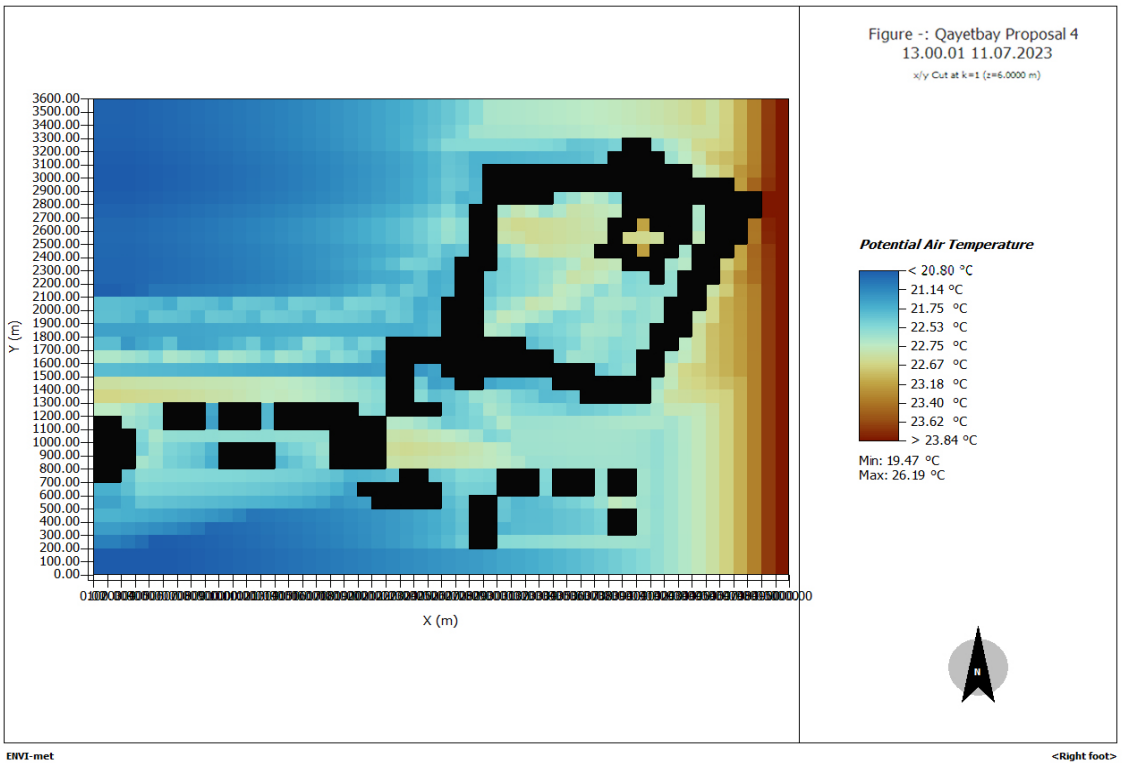

Figure 24. Scenario four map of potential air temperature, Source: Envi-met analysis after simulation using LEONARDO.

3.8. Discussion and Results:

The researcher made the questionnaire according to the literature review study of Gehl's theory and restorative urban design of public spaces to reach users comfort in plaza and mental health. In contribution, to the study of urban heat island and users' comfort and the effect of surface covering material on the rise of temperature and users stand and stay in place. As from the main aspect to reach restorative public space for users' mental health and wellbeing is adding greeneries and water elements. These elements are also used to decrease surfaces exposed to the sun that directly decrease the temperature and enhance users' thermal comfort. That the public space become more inclusive for users and enhance there stay in the space. While Alexandria in the latest decade is facing a huge increase in temperature due to huge urbanization and heat absorbing covering materials. Thus, the best solution is to use cool material.

As, questionnaire results shows that people don't feel comfortable in Qaitbay plaza, and almost 75% of people found that the material and dark asphalt caused heat and thermal discomfort as there are no shelters or shades, dark materials that absorb heat, not enough vegetation, the need of more accessible pathways, more parking lanes, safety (cameras) and the need of more seatings to improve their stand and stay in the plaza and make it more inclusive, heat management improvement and more amenities. To reach users comfort inside the plaza. By applying these suggestions, the plaza will become more functional, attracting and appealing for users.

The simulation's findings show that adding cool pavement materials, vegetation, and a water feature to the surfaces matters more than a street's orientation toward the sun. The previously displayed colored maps show the difference in surface air temperature before and after cool paving materials were added to the sidewalk and road to reduce urban heat island effect and improve pedestrian thermal comfort. As shown in (Table 5); the impacts of various cool paving materials and the evaluation of the current situation and 4 scenarios on the temperature and heat island. As a result, the number of factors, including population density, pedestrian activity, CO_2 emissions, and characteristics of urban surfaces like invulnerable Albedo, and greenery, surface temperature may play a significant role in mitigating urban heat island effect and reducing heat stress.

Table 5. Show the effect of the change in material, vegetation, water on simulation, Source: Researchers.

Proposal	Time	Sidewalk Material	Road Material	Greenery	Water Elements	Min. Temp.	Max. Temp.
Current Situation	1:00 pm	Dark Interlock tiles	Dark Asphalt	No	Sea	21.53 ^{0}C	29.78 ^{0}C
Scenario 1		Dark Interlock tiles	Dark Asphalt	Yes	Yes + Sea	21.53 ^{0}C	29.78 ^{0}C
Scenario 2		Colored Asphalt	Brick Stone	Yes	Yes + Sea	20.94 ^{0}C	28.87 ^{0}C
Scenario 3		Colored Asphalt	Concrete Light color	Yes	Yes + Sea	20.21 ^{0}C	27.23 ^{0}C
Scenario 4		Basalt	Granite	Yes	Yes + Sea	19.47 ^{0}C	26.19 ^{0}C

Figure 25. The public space after changing some materials, adding vegetation and water elements, Source: 3D Max by the researchers.

Figure 26. The public space after changing some materials, adding vegetation and water elements, Source: 3D Max by the researchers.

The validation of the the ENVI-met simulation results focuses in mostly on surface materials and plant coverings. By utilizing the proper characteristics, the surface temperature is remitted by 3.6 degrees Celsius, especially in the scenario 4. This is achieved by adding trees, vegetation, and some water features beside the presence of the sea, besides using granite for the sidewalk and basalt for the road (Figures 25 and 26). These estimates confirm the significance of the impact of surface materials on users' thermal comfort and the enhancement of the urban microclimate that has a direct impact on improving mental health and wellbeing. The difference between the actual measure of the scenarios showed reduction in temperature and enhance in humidity regarding to the actual measures in July 2023.

4. Conclusion

The Urban heat island effect (UHI) and rising temperatures due to local climate change significantly impact building energy consumption and pedestrian thermal comfort in outdoor urban areas. UHI affects social, economic, and ecological issues, affecting users' mental health and wellbeing. Various approaches have been proposed according to the questionnaire results to address this issue, including surface paving materials and restorative urban design. In Qaitbay citadel plaza, cool pavements were used to control UHI, reducing surface air temperatures and demonstrating a significant reduction in UHI effects.

This study mitigated the urban heat island effect in the case study area by using cool covering materials on pedestrian area. Cool pavements are effective in improving outdoor thermal environments, especially during summer months. Simulation techniques show that cool materials lower air temperature on surfaces covered with these materials. However, this study found that congested layouts result in less outdoor thermal comfort than current situation. The study recommends testing and evaluating cool covering materials to optimize urban ground cover materials and improve the thermal environment for outdoor users.

Measurements using Envi-met were used to validate the proposed or chosen ground cover by comparing the measured and identical ground cover materials in citadel Qaitbay citadel plaza. This study reveals that urban areas become more adaptable to UHI. The amount of thermally reflecting pavement materials decreases the amount of absorbed heat. The study also found that the thermal performance of urban composition is influenced by parameters involving different materials, such as interlocking and asphalt roads. Asphalt roads significantly affected the temperature of the urban form, while interlocking roads had a smaller impact. This research suggests that considering more coolpaving materials can help lower UHI. The study emphasizes the importance of considering more coolpaving materials to reduce UHI in urban areas.

This research improved the thermal comfort and human wellbeing of Qaitbay citadel plaza's users by replacing the paving materials and adding shades, lightings, trees, open air theatre. It explores mitigating factors like vegetation, Albedo factor, and building facades and orientations to reach users thermal comfort, mental health and wellbeing. The research found the strong relation between urban heat island (users' thermal comfort) and users mental health and wellbeing, thus to reach a successful restorative urban public space, you should reach user thermal comfort inside the space.

5. Limitation of the Study

The study limitations are:

1. The location of the site with different climate, layout, and population.
2. The questionnaire was applied only with 92 participants that may change according others perspectives, beside it measures how user feel inside the place that differs from one to other.
3. The analysis was specifically done on summer condition that could differ from season to another.
4. The ENVI-met simulations depend on specific assumptions about material properties and vegetation that may not capture all real-world.
5. The paper mainly focuses on thermal comfort, other dimensions of mental well-being, such as noise and air quality, were not explained.

6. Future Research

AI technology would be used in the future research to measure level of satisfaction of users inside the space, beside measuring the surrounding climate change and temperature to make sure users feel comfortable inside the space.

Author Contributions

Mayar Tarek Metwally wrote the main manuscript text and prepared all figures. Sherine Shafik Ali and Abdelaziz Farouk A. Mohamed reviewed the manuscript. All authors approved the manuscript.

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Conflict of Interest Statement

The authors declare no competing interests of this manuscript.

Data Availability Statement

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

References

A. Tzavali, J. P. (2015). Urban Heat Island Intensity: A Literature Review. *Fresenius Environ. Bull., 24*(12), 4537–4554. https://www.researchgate.net/publication/298083233_Urban_heat_island_intensity_A_literature_review

Al-Hadid, A. (2023). The challenges of thermal comfort and mental well-being in historical urban spaces: A case study of Qaitbay Citadel Plaza in Alexandria, Egypt. *In Proceedings of the International Conference on Urban Comfort and Heritage Preservation* (pp. 45-56). Alexandria University Press. Retrieved from https://link.springer.com/chapter/10.1007/978-3-030-65421-4_4#:~:text=1.%20REALCOOL-Really%20Cooling

Ali-Toudert, F. (2007). hermal comfort in an outdoor urban street canyon in the Mediterranean climate: A sensitivity analysis on the influence of urban street design. *Building and Environment, 42*(3), 1553-1560. doi:https://doi.org/10.1016/j.buil

Barton, H. (2000). *Healthy urban planning: A WHO guide to planning for people.* Spon Press. doi:https://doi.org/10.4324/9780203857755

Basics, U. H. (2011). Reducing Urban Heat Islands: Compendium of Strategies. *14.* US EPA: https//www.epa.gov/heatisland/resources/compendium.

Beatley, T. (2016). *Handbook of Biophilic City Planning & Design.* Island Press. Retrieved from https://islandpress.org/books/handbook-biophilic-city-planning-design.

Bek MA, A. N. (2018). The effect of unplanned growth of urban areas on heat island phenomena. *Ain Shams Eng J (ASEJ), 9*(31), 69–77.

Bowler, D.E., Buyung-Ali, L., Knight, T.M., & Pullin, A.S. . (2010). *Urban greening to cool towns and cities: A systematic review of the empirical evidence. Landscape and Urban Planning* (Vol. 3). doi:10.1016/j.landurbplan.2010.05.006

CABE. (2010). Retrieved from The Value of Public Space. https://www.designcouncil.org.uk/sites/default/files/asset/document/The_Value_of_Public_Space.pdf

D. Zhou, S. Z. (2014). Surface Urban Heat Island in China's 32 major cities: Spatial patterns and drivers. *Remote Sens. Environ.,, 152*(7), 51-61.

D.E. Bowler, L. B.-A. (2010). Urban greening to cool towns and cities: a systematic review of the empirical evidence. *Landsc. Urban Plann.*, 97(3): 147-155.

D.P. Johnson, A. Stanforth, V. Lulla, G. Luber. (2012). Developing an applied extreme heat vulnerability index utilizing socioeconomic and environmental data. *Appl. Geogr., 35(1)*, 23-31. Retrieved from https://doi.org/10.1016/j.apgeog.2012.04.006.

EEA, E.E. (2012). Urban Adaptation to Climate Change in Europe. *Challenges and Opportunities for Cities Together with Supportive National and European Policies*.

Egypt., S. (2023). *Climate Data.* . Retrieved from https://climateknowledgeportal.worldbank.org/country/egypt/climate-data-historical

Elwan, A. F. (2017). Urban climate challenges in Mediterranean coastal cities: Case of Alexandria, Egypt. *Journal of Urban Climate, 22*, 58 - 66. doi:https://doi.org/10.1016/j.uclim.2017.06.007

EPA, U. (2011). Basics U. H. I. Reducing Urban Heat Islands: Compendium of Strategies. *14*.

Ferguson B, F. K. (2005). Reducing Urban Heat Islands: Compendium of Strategies (Cool pavements). *Cambridge Systematics*.

Forum. (2023). *World Economic Forum. Why public spaces are a basic need for cities.* World Economic. Retrieved from: www.weforum.org/agenda/2023/05/public-space-cities-urban-planning/

Gehl, J. (1987). *Life Between Buildings: Using Public Space* (2011 revisited ed ed.). (J. Koch, Trans.) New York, Van Norstrand Reinhold. www.amazon.com

Gehl, J. (2010). *Cities for People. Island Press.* https://islandpress.org/books/cities-people#desc

Gehl, J. (2011). Life Between Buildings: Using Public Space. *Island Press. Retrieved from*. Retrieved from https://islandpress.org/books/life-between-buildings. https://islandpress.org/books/life-between-buildings

Genecon LLP. (2008). *The Trust for Public Land 2009.* https://issuu.com/hellojennyelliott/docs/designing_public_spaces_for_health_

Gómez-Baggethun, E. &. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics, 86*, 235-245. doi:https://doi.10.1016/j.ecolecon.2012.08.019

Gong, N. C. (2013). MODIS Detected Surface Urban Heat Islands and Sinks: Global Locations and Controls. *Remote Sens. Environ., 134*, 294 - 304. doi: https://doi.org/10.1016/j.rse.2013.03.015

Grahn, P., Stigsdotter, U. K., & Nilsson, P. (2010). *Outdoor environments and health - is there a relationship? .* Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2804629/

Heaviside, C., Cai, X-M., & Vardoulakis, S. (2015). The effects of horizontal advection on the urban heat island in Birmingham and the West Midlands, United Kingdom during a heatwave. *Quarterly Journal of the Royal Meteorological Society, 141*. doi:https://doi.org/10.1002/qj.2452

Robine, J.-M., Cheung, S.L.K., Le Roy, S., Van Oyen, H., Griffiths, C., Michel, J.-P., Herrmann, F.R.. (2008). Death toll exceeded 70,000 in Europe during the summer of 2003. *Comptes Rendus Biol. , 331(2)*, 171-178.

JA., V. (2004). Urban Heat Islands: Hotter Cities. *Actionbioscience E-Newsletter*.

Johnson et al. (2012). *Environmental Stressors and Health Impacts in Urban Environments. Sustainability* (Vol. 14). doi:org/10.3390/su14159234

K. Lässig, R. L. (1971). Beispiele zur Gestaltung städtebaulicher Räume. (V. f. Prof. Dr. e.h. Hans Schmidt, Ed.) *Mit einer Einführung von*.

Yenneti, K.. (2020, March). *After another hot summer, here are 6 ways to cool our cities in future.* Retrieved from http://theconservation.com.

Kaplan, R., & Kaplan, S. (1989). *The Experience of Nature: A Psychological Perspective. Cambridge University Press.* https://books.google.com.eg/books

Keith, L., & Meerow, S. . (2021). *Planning for Urban Heat Resilience. .* American Planning Association. PAS Report 600. Retrieved from https://www.planning.org/publications/document/9214815

Kessler, R. C., Andrews, G., Colpe, L. J., Hiripi, E., & Mroczek, D. K. (2002). Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychological Medicine, 32*(6), 959–976. doi: https://doi.org/10.1017/S00

Keyes, C. L. (2005). *Mental Illness and/or Mental Health? Investigating Axioms of the Complete State Model of Health* (Vol. 3). *Journal of Consulting and Clinical Psychology*. doi: https://doi.org/10.1037/0022-006X.73.3.539

Klemm W., & Lenzholzer S. (2017). Developing green infrastructure design guidelines for urban climate adaptation. *Journal of Landscape Architecture, 12*(13), 60–71. doi:https://doi.org/10.1080/18626033.2017.1347256

Klemm, W. &. (2017). The cooling effects of urban green infrastructure. *Landscape and Urban Planning, 157*, 239–254. doi:https://doi.10.1016/j.landurbplan.2016.08.006

Klemm, W., & Lenzholzer, S. . (2017). The cooling effects of urban green infrastructure:. *A review. Landscape and Urban Planning, 157*, 239 - 254. doi:https://doi.org/10.1016/j.landurbplan.2016.08.006

Klemm, W., & Lenzholzer, S. (2017). Developing green infrastructure design guidelines for urban climate adaptation. *Journal of Landscape Architecture, 12*(13), 60–71. doi:https://doi.10.1080/18626033.2017.1347256.

Kovats, R.S., & Hajat, S. (2008). *Heat stress and public health: A critical review. Annual Review of Public Health, .* https://doi.10.1146/annurev.publhealth.29.020907.090843

Kovats, S. &. (2008). *Climate Change and Public Health: Impacts of Heatwaves in Urban Areas. Environmental Health Perspectives* (Vol. 9). doi:https://doi.org/10.1289/ehp.11247

Kuo, F. E., & Sullivan, W. C. (2001). *Environment and crime in the inner city: Does vegetation reduce crime? Environment and Behavior* (Vols. 33(3), 343-367, 33(4), 543-571). doi:https://doi.10.1177/0013916501333002

Lässig, K. (1971). *Design variations in public space geometry and infrastructure.* doi:https://doi.org/10.1016/j.scs.2020.102592

Leyden, K. M. (2003). *Social capital and the built environment: the importance of walkable neighborhoods.* (Vol. 9). American Journal of Public Health. doi:https://doi.10.2105/AJPH.93.9.1546.

Lotfi Y, R. M. (2019). Veritcal gardens as a restorative tool in urban spaces of New Cairo. *Ain ShamsEngJ (ASEJ)*. https://www.researchgate.net/publication/338470343_Vertical_gardens_as_a_restorative_tool_in_urban_spaces_of_New_Cairo

M. Demuzere, K. O. (2014). Mitigating and adapting to climate change: multi-functional and multi-scale assessment of green urban infrastructure. *J. Environ. Manag.*, 107-115. doi:https://doi.10.1016/j.jenvman.2014.07.025.

M. N. Hamoodi, R. C. (2019). Thermophysical Behaviour of LULC Surfaces and their Effect on the Urban Thermal Environment. *J. Spat. Sci., 64*(1), 111-130. doi:https://doi.10.1080/14498596.2018.1505275.

Hendel, M. (2016). Pavement-watering in Cities for Urban Heat Island Mitigation and climate Change Adaptation: A Study of its Cooling Effects and Water Consumption in Paris. Engineering Sciences. *Universite Paris Diderot, Paris*.

Santamouris, M. (2014). Cooling the cities– a review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. *Sol. Energy*, 682–703. doi:https://doi.10.1016/j.solener.2012.07.003.

Maas, J. V. (2006). *(2006). Social Contacts as a Possible Mechanism Behind the Relation Between Green Space and Health* (Vol. 4). Health & Place. doi:https://doi.10.1016/j.healthplace.2005.02.003.

McCAY, J. R. (2019). *Restorative Cities Urban Design for Mental Health and Wellbeing.* https://www.who.int/news-room/fact-sheets/detail/mental-health-strengthening-our-response/?gad_source=1&gclid=CjwKCAiA9IC6BhA3EiwAsbltONsH0BWrrTHaHI0kwbRTIJzwqidTtBrji57W4_iaFrs4WhQRNvxfXRoCqoUQAvD_BwE

Mohamed, A. (2023). Climate of Alexandria. https://researchgate.net/publication/332245958_LONG-TERM_TRENDS_OF_EXTREME_CLIMATE_EVENTS_OVER_ALEXANDRIA_REGION_EGYPT

Mohamed, A. F. (2011). *"An Ecological Residential Buildings Management" MSc thesis, Arab Academy for Science, Technology and Maritime Transport, Egypt. Published Book at Lambert.* Academic publishing.https://www.amazon.com

Mohamed, A. F. (2023). A Study of Strategic Plans of Sustainable Urban Development for Alexandria, Egypt to Mitigate the Climate change phenomena. *Future cities and Environment*. doi:https://doi.org/10.5334/fce.158

Northridge, M. E., et al. (2003). "Sorting out the connections Between the Built Environment and Health: A Conceptual Framework for Navigating Pathway and Planning Healthy Cities.". *Journal of Urban Health 80 (4)*, 556 - 568. Retrieved from doi:10.1093/jurban/jtg064

Norton, B.A., Coutts, A.M., Livesley, S.J., Harris, R.J., Hunter, A.M., & Williams, N.S.G. . (2015). *Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. Landscape and Urban Planning.*

Oke, I. D. (2012). *Local Climate Zones for Urban Temperature Studies* (Vol. 93). Bull. Am. Meteorol. Soc.DOI: https://doi.org/10.1175/BAMS-D-11-00019.1

Oke, T. (1976). The Distinction between Canopy and Boundary Layer Urban Heat Islands. *Atmosphere, 14*(4), 268-77. doi: doi/abs/10.1080/00046973.1976.9648422

Padmanaban R, B. A. (2019). Satellite image fusion to detect changing surface permeability and emerging urban heat islands in a fast-growing city. *PLoS ONE., 14*(1). https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0208949

Pretty, J. P. (2005). *The mental and physical health outcomes of green exercise.* (Vol. 5). International Journal of Environmental Health Research. https://pubmed.ncbi.nlm.nih.gov/16416750/

Programme, U. N. (2022). *Climate Change and Health*. https://www.un.org/en/climatechange

R. Hansen, A. O. (2019). Planning multifunctional green infrastructure for compact cities: what is the state of practice? *Ecol. Indicat*, 99-110. https://research.wur.nl/en/publications/planning-multifunctional-green-infrastructure-for-compact-cities-

Kovats, R.S., Hajat, S. (2008). R.S. Kovats, S. Hajat, Heat stress and public health: a critical review, Annu. Rev.Public Health. *29 (1)*, 41–55. doi: https://doi.org/10.1146/annurev.publhealth.

Raven, R., et al. (2014). Enhancing urban resilience to climate change: a strategic approach for cities in the global south. Urban Climate. *9*, 77-94. doi: https://doi.org/10.1016/j.uclim.2014.06.004

Ridha, S. (2017). Urban Heat Island Mitigation Strategies in an AridClimate: Outdoor Thermal Comfort Reachable. *Civil Engineering INSA de Toulouse*. https://theses.fr/?domaine=theses

Riham Nady Faragallah & Riham A. Ragheb, Evaluation of thermal comfort and urban heat island through cool paving materials using ENVI-Met. doi:https://doi.org/10.1016/j.asej.2021.10.004

Robine, J.-M., Cheung, S.L.K., Le Roy, S., Van Oyen, H., Griffiths, C., Michel, J.-P., & Herrmann, F.R. . (2008). *Death toll exceeded 70,000 in Europe during the summer of 2003. Comptes Rendus Biologies* (Vol. 331). doi: 10.1016/j.crvi.2007.12.001.

Santamouris, M. (2014). *On the energy impact of urban heat island and global warming on buildings. Energy and Buildings* (Vol. 82). doi:10.1016/j.enbuild.2014.07.022.

Stephanie Y. S. Cheung , Danyang Lei , Faye Y. F. Chan , and Hendrik Tieben. (2022). *Public Space Usage and Well-Being.* doi: https://doi.org/10.17645/up.v7i4.5764.

Studies., L. C. (2021). *Urban Heat Islands in Alexandria.*

T. Stocker, G.-K. P. (2013). IPCC Climate Change: The Physical ScienceBasis-Findings and Lessons Learned. *EGU General Assembly Conference Abstracts*, (p. 17003).

T. Zölch, J. M. (2016). Using green infrastructure for urban climate-proofing: an evaluation of heat mitigation measures at the microscale. *Urban For. Urban Green*, 305–316. doi: https://doi.org/10.1016/j.ufug.2015.07.013.

Taha, H. (1997). Urban climates and heat islands: Albedo, evapotranspiration, and anthropogenic heat. *Energy and Buildings, 25*(2), 99-103. doi:https://doi.org/10.1016/S0378-7788(96)00999-1

Taleghani, M. (2018). Outdoor thermal comfort by different heat mitigation strategies. *review, Renew. Sustain. Energy Rev.* doi: https://doi.org/10.1016/j.rser.2017.06.010

Taleghani, M. (2018). *Outdoor thermal comfort by different heat mitigation strategies: A review Renewable and Sustainable Energy Reviews,* (Vol. 81). doi: https://doi.org/10.1016/j.rser.2017.06.010.

TR., O. (1979). Oke TR. The Distinction between Canopy and Boundary Layer Urban Heat island . *atmosphere*, 14(4): 77-268. doi: https://doi.org/10.1080/00046973.1976.9648422

(n.d.). *U.S. Environmental Protection Agency. Urban Heat Island Basics: Reducing Urban Heat Islands.* Retrieved from https://www.epa.gov/heatislands/reducing-urban-heat-islands-compendium-strategies.

Van den Berg, A. E.-V. (2010). Health benefits of green spaces in the living environment: A systematic review of epidemiological studies. *Urban Forestry & Urban Greening, 14*(4), 806 - 816. doi:https://doi.10.1016/j.ufug.2015.07.008

Vardoulakis, S., Dimitroulopoulou, S., Thornes, J.E., Lai, K-M., Taylor, J., Myers, I., et al. (2015). Impact of climate change on the domestic indoor environment and associated health risks in the UK. *Environmental International*, 299-313. doi:https://doi.org/10.1016/j.envint.2015.09.010

vidsen D, Green J. (2019). *Sustainable Residential Design: Using Low Impact Materials.* Retrieved from www.asla.org.

Voogt JA, Oke TR. (2003). Thermal remote sensing of urban climates. *J Remote Sens Environ 2003, 86*(3), 370–84. doi: 10.1016/S0034-4257(03)00079-8

W. Klemm, S. L. (2017). Developing green infrastructure design guidelines for urban climate adaptation. *Journal of Landscape Architecture*, 60-71. doi:10.1080/18626033.2017.1352240.

Wang C, W. Z. (2021). Cool pavements for urban heat island mitigation: a synthetic review. *Renew Sustain Energy.* doi:https://doi.org/10.1016/j.rser.2021.111171

WHO. (2001). *The World Health Report. Mental Health: New Understanding, New Hope. Geneva: World Health Organization.* https://iris.who.int/handle/10665/42390

WHO, W. H. (2014). Global Status Report on Non Communicable Diseases. https://www.who.int/publications/i/item/9789241564854

Wilkinson, P. S. (2009). Public health benefits of strategies to reduce greenhouse-gas emissions: Household energy. *The Lancet, 374*(9705), 1917-1929. doi: https://doi.org/10.1016/S0140-67

Wilkinson, P., Smith, K.R., Davies, M., Adair, H., Armstrong, B.G., Barrett, M., et al. (2009). *Public health benefits of strategies to reduce greenhouse-gas emissions: household energy* (Vol. 374). The Lancet. doi:https://doi.org/10.1016/S0140-6736

Wood, L. H.-C. (2013). *Public Green Spaces and Positive Mental Health - Investigating the Relationship Between Access, Quantity, and Type of Parks and Mental Well-being.* (Vol. 19). Health & Place. doi:https://doi.org/10.1016/j.healthplace.2017.09.002

Yinghong., Q. (2015). A review on the development of cool pavements to mitigate urban heat island effect. Renew Sustain Energy. 445–59. doi:https://doi.org/10.1016/j.rser.2015.07.177