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Biophilic design as a tool to enhance environmental performance under flyovers.

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Abstract

Due to the increase in population and movement between cities, the number of flyovers has increased to facilitate the move between different areas in cities that led to high car traffic. As a result, carbon emissions and pollution have increased, affecting the air temperature and quality in urban areas. Therefore, this paper studies how to improve the environmental performance under the flyovers in cities. The research's aim can be fulfilled through biophilic design that works on the vitality of urbanization and integration with nature, as it promotes green infrastructure. This paper deals with the study of flyovers, their characteristics, and the necessary criteria for obtaining effective areas below them, biophilic design for urbanization, and the principles and criteria for its use to improve environmental performance under the areas of flyovers, with an analysis of examples of effective handling of flyovers. The paper focuses on a case study at the areas under the flyovers in Alexandria Square in Tanta city and its analysis before and after the biophilic treatment using the environmental simulation program Envi-met. The proposed design can reduce the value of PMV by about 35% from its current state during the hours of solar presence to achieve thermal satisfaction.

1. Introduction

More than one half of the world's population now lives in cities. According to a report by the United Nations (UN), urbanization could add another 2.5 billion people to urban areas by 2050 [1].

The urban expansion in cities has led to an increase in the use of cars and an increase in traffic that in turn has led to an increase in overpasses to facilitate movement between different regions, and this has led to an increase in urban pollution and the heat island phenomenon. The lack of attention to the shape and employment of overpasses has led to the loss of many spaces under them, which affected the urban and social fabric as well as its negative impact on the environmental performance of urbanization, as these areas are considered risky and negative places [1], [2]. These places are seen as remaining, not-cared-about and ignored spaces. However, many architects and urbanists consider

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these spaces as potential places that are to be transformed into distinctive spaces the introduce visual pleasure and outstanding environmental and social performance [3]. Also, the remaining and unexploited spaces in urbanization, such as public tunnels, places under overpasses, as well as gaps between buildings, spaces around railway roads and spaces next to highways represent spaces that can be positively used to be environmentally friendly and beneficial for the city. The biophilic design of urbanization represents a strategy to achieve a life-loving urbanization that works to restore the relationship between man and nature, as it improves the living environment for humans and mitigates environmental and climatic problems as well as urban problems, to achieve thermal, visual, and psychological comfort for users. Therefore, the research aims to try to develop a mechanism to improve environmental performance in the areas of overpasses and under them using biophilic design for urbanization and the promotion of green infrastructure.

The problem: The research problem is to consider the areas below the flyovers as residual unexploited areas, despite their large areas and their privileged location in some cases where they are used in the best cases as parking lots. The overpasses were built without taking into account the environmental, social, and psychological considerations of the population, which increased the environmental problems in urbanization due to carbon emissions and air pollution, as well as the lack of lighting and natural ventilation below, besides the phenomenon of urban heat island in those areas of the existing cities.

The aim: The research aims to exploit the unused places within the areas of and beneath the overpasses to improve the environmental performance of the urbanization, through the use of nature and the elements of biophilic urbanism to confront climate change, achieve thermal comfort and reach a sustainable and flexible urbanization.

Methodology: This research methodology is as follows:

Theoretical methodology:

Studying overhead bridges and their bottom surfaces, the most important weaknesses and disadvantages of these areas, their role, and different characteristics, in addition to the necessary factors to reach effective areas under overhead bridges. Also studying the biophilic design of urbanization, its dimensions, and elements, in addition to reaching the foundations of criteria for using biophilic design to improve environmental performance under overhead bridges. Analyzing some examples of areas below overhead bridges and dealing with them according to the dimensions of the biophilic design for urbanization.

Applied methodology:

The research deals with a case study of the areas beneath bridges in Alexandria Square and next to the railways in Tanta. The research analyzes the situation before and after biophilic design through the use of environmental simulation program Envi-met to find out the extent of its impact on the environmental performance of urbanization.

2. Overhead bridges (flyovers)

Overhead bridges are mainly designed to solve traffic and mobility problems, especially in cities with high traffic. A bridge is a structure that provides a passage over a natural (river) or man-made place (road) for vehicle traffic. Bridges are the largest and most distinctive human-made structures of the modern era. [4] flyovers are implemented in cities to meet mobility needs. They are seen as a symbol of modernity and aiming to ease traffic congestion, support economic development, and improve connectivity between the spaces below. They are like vertical walls separating adjacent areas. The huge expansion of the overpasses led to the loss of much of the space underneath. In turn, bridges affect the city and its urban fabric, its identity and its environmental and psychological impact. Therefore, it has become vital to focus on studying those areas to have them environmentally, socially, and urbanely developed.

3. Public spaces under flyovers

The areas below flyovers represent spaces created by bridges and are usually considered asphalt-covered pavement, which are not used in most urban areas [5]. They are seen as neglected places that are mostly used as parking lots. These spaces emerge as a result of inefficient and inappropriate planning processes implemented without an understanding of the city's fabric [2], [6].
However, these areas can be used as small public spaces that positively affect urbanization and the lives of residents, as well as improve environmental performance.

3 .1. The most important weaknesses and negatives in the public spaces under the flyovers

Public areas under flyovers, if neglected, have a significant impact on urbanization, whether functionally, visually, socially, and psychologically.

3 .1.1. Functionally

- It is represented as being neglected and missing spaces, of undefined use. [7]
- These areas are usually used as parking spaces, in addition to irregular activities that are specified by users. The infringement is used by individuals to illegally park vehicles. [8]
- Homeless people also crawl over these areas as shelters that protect them from harsh weather conditions. These areas are used as landfills, which creates environmental risks to neighboring areas [7].

3.1.2. Visually

- It is formed according to the superstructure and structural columns in addition to the adjacent streets, which form the physical form of the site [8]. Its shape represents a structure that dominates the urban fabric, Representing visual separation between the urban areas and the surrounding [7]. Decreased natural lighting and ventilation under overhead bridges is inevitable.

3 .1.3. Socially and psychologically

- They also lead to negative physical and psychological health conditions, with increased noise and air pollution, especially within residential areas. [7]
- These lost spaces lead to the existence of urban areas in which there is no security with an increase in violence, in addition to being areas that reduce social interactions among the population. [8]

This is in addition to its environmentally negative impact on air quality and thermal comfort in urban areas, as well as noise that affects the auditory comfort of the population. Therefore, the trend was to find out the most important characteristics and considerations of those spaces, and to reach the most important criteria and factors that make these spaces effective and useful.

3.2. Characteristics of the areas under the flyovers.

With the increase in population and lack of open spaces in the city, the area under flyovers has made a void with great potential. There is a need for public spaces within the city to improve the environmental performance of urbanization and to achieve some aesthetic considerations and achieve a good functional performance of it. The characteristics that distinguish these urban areas are represented in: [8], [9].

Inevitability: The space under flyovers is an inevitable product that is created during the urban development process, and it must be exploited in a positive urban and environmental way.
Dynamic nature: They are areas of a dynamic nature, as they are not static. Where the use of areas under the flyovers is due to the needs of the population and the local environment, which makes these spaces of a dynamic and changing nature.
Link and integration: Exploiting the spaces under the bridges to enhance the efficiency and effectiveness of the city. By achieving good integration with the surrounding areas and working to achieve interdependence between the surrounding urban elements.

4. Criteria for achieving effective spaces under flyovers.

To properly develop spaces under flyovers, a set of criteria must be met. For the site to become effective, it should be able to utilize the space with the best capabilities that affect the people and the place positively.

4.1. Environmental standards

4.1.1. Protection from air pollution

Due to the increase in car traffic in city centers and bridge areas, air pollution caused by carbon emissions from vehicles in addition to heat emissions has become an important matter to air quality in cities. It has become necessary to work on designing the urbanization of these areas to protect the air from pollutants and oxides [9].

4.1.2. Noise protection

The large number of cars on the roads and overpasses increases the noise, and the space under the overpasses is affected by the noise. Therefore, these spaces must be protected from the noise of traffic with more effective elements for generating a positive impact. [8], [9].

4.1.3. Trees and Green Spaces

Overpasses and areas under them are dominated by gray area. So, green spaces are of great environmental importance. Trees and green areas play a vital role in mitigating the phenomenon of heat island and environmental pollution, achieving thermal comfort.

4.1.4. Access to a clean environment

Using recycling bins to preserve the environment leads to having clean streets and walkways.

4.2. Urban standards

Areas to facilitate access to public transportation, by merging the spaces under flyovers with traffic. The flow of pedestrian traffic: the presence of paths for the flow of pedestrian traffic helps to reach the voids and places under bridges and the surrounding areas easily. [9].

4.3. Social standards

Working on flyovers and areas under them will lead to obtaining comfortable and safe spaces by providing comfortable open spaces for users, providing safety in movement and sitting. It also leads to obtaining spaces that provide a sense of safety through providing good lighting under the overhead bridges. [10]. It also provides attractive spaces with an aesthetic appearance, where places beauty affects the users psychologically and socially.

4.4. Economic standards

The use of the spaces under the overpasses leads to the development of the business environment, in which various activities can be carried out, which work to enhance the economic aspect.
The previous criteria represent some of the considerations that must be followed to obtain effective areas under the flyovers, the most prominent of which is the environmental considerations because of their impact on the thermal, audio-visual comfort of people in those areas. This is reinforced by the factors that must be followed to reach good urban spaces.

5. Urban factors to reach good urban spaces under the overhead bridges

Citizens can make good changes in their communities in neglected areas, through four main qualities. Fig 1 [11], [12].

5.1. Access and Linkages

Ease of access and movement is achieved by having a clear relationship between the spaces under the flyovers and the surroundings [13], [14], in addition to creating efficient and lively public spaces.[12]

5.2. Comfort & Image

It leads to maintain a comfortable space and an attractive image to accommodate people under the overhead bridges and achieve audio-visual comfort for them. [15] This is done through the comfort of the senses by reducing noise [16], as well as visual coherence by striving to connect the population visually with those spaces in innovative forms and ways. [17]

5.3. Users & Activities

One of the key features of successful public spaces is the activities that take place within them, where the spaces under the overpasses are used as green paths and recreational places for picnics.

5.4. Sociability

The presence of people is what makes the urban spaces work in interaction. The programming of the site must be directed to users, as it achieves and stimulates social interaction between people, which increases the connection to the place.

Fig 1: What makes a great space [11] , [12]

From the above, environmental standards represent an important aspect that greatly affects the areas of overpasses and under them. The intensity of vehicular traffic affects urbanization's thermal performance and air quality. Therefore, the research tended to study the role of the vital design for urban expansion in improving the environmental performance in the areas of the upper and lower bridges to achieve the required thermal comfort and air quality.

6. Biophilic design to handle areas under flyovers.

6.1. Biophilic Design for Urbanism

The word Biophilia means the innate tendency to focus on life and lifelike processes [18]. The world is now heading towards biophilic cities, by integrating nature with the urbanization of cities [19], where natural landscapes are brought into urbanization, as well as within buildings, walls, and roads to give nature to every element of the built environment [20]. The biophilic design of urbanization helps in cooling the city, especially with climate change, in addition to dealing with the heat island phenomenon, besides its role in reducing energy needs and improving biodiversity and health for the population [21].

Fig 2: The six measures of biophilic design for urbanization [21].

6.2. Biophilic cities

Biophilic cities are cities that provide close, daily contact with nature, promote awareness of and concern for nature, and are also sustainable and resilient. It works to enhance social resilience, landscapes, and climate change [21]. Biophilic cities involve residents in integrating nature with urbanism.

Beatley outlines six measures of the built environment (buildings, blocks, streets, neighborhoods, communities, and areas). The best biophilic cities are those where these successive measures overlap and reinforce biophilic behaviors and lifestyles, Fig 2. [21].

These six measures focus on the use of the green element inside and outside the building, and the use of plants in the green urban networks in the streets, urban spaces, walls, fences, and various roads. This is what the research is based on, i. to deal with the areas of the flyovers and under them to improve the environmental performance and achieve thermal, visual, and psychological comfort for the users in those areas. The biophilic design patterns for cities depend on eleven patterns based on communication with nature in different ways and forms. These patterns are summarized in the visual, visible and invisible contact with nature, the connection with nature sensually and physically, and the role of that biophilic design in thermal change and air movement in urban areas [22].

The use of biophilic design is preferable to be integrated elements, to produce a comprehensive integrated environmental unit. It includes three types of nature that represent the basic categories of our biophilic design framework Fig3 [23].

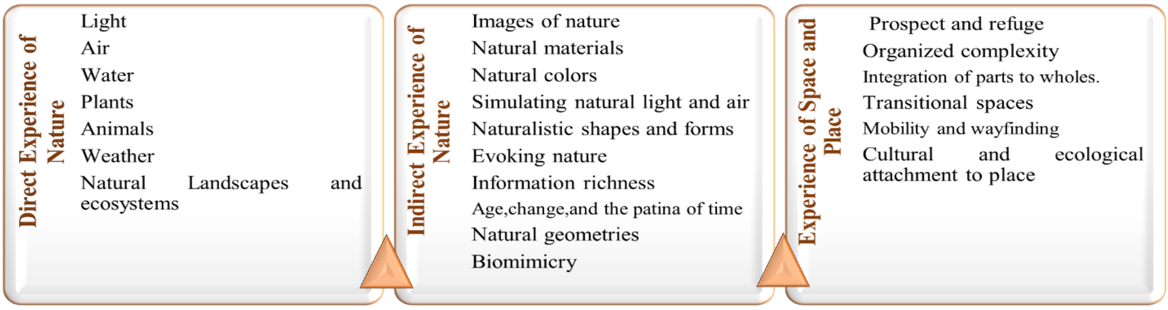


Fig 3: The three types of nature at biophilic design [23].

It includes the direct experience of nature, the indirect experience of nature, and the experience of space and place. The direct experience of nature refers to the actual connection with environmental features in the built environment including natural light, air, plants, animals, water and landscape. The vicarious experience of nature refers to contact with a representation or image of nature, the transformation of nature from its original state or exposure to certain patterns and processes characteristic of the natural world. They include photos and artwork, natural materials such as wood furnishings and woolen fabrics, along with decoration inspired by nature. Finally, the experience of space and place refers to distinct spatial features of the natural environment that have promoted human health.

These points were merged, and 15 elements were extracted for the environmentally integrated biophilic design, whether by direct or indirect experience of nature, besides spatial features, which are illustrated by Fig4. [24], [25],[26].

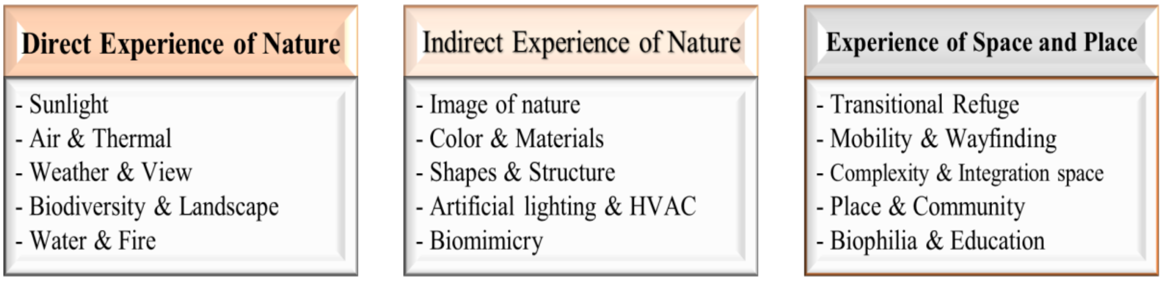


Fig4: biophilic experience integrated elements [24], [25],[26]

Herein under, these elements are linked with the considerations and related factors to the construction of the areas of overpasses and under them, to find out the most important foundations and criteria that can be used in urban biophilic design to improve environmental performance in areas below flyovers. [27]

7. Principles of using biophilic design to improve environmental performance in areas under flyovers.

Where it clarifies the relationship between the elements of biophilic design and considerations for improving the environmental performance of the building, including thermal comfort, visual comfort, auditory comfort, and air quality.as show in Table 1.

Table 1: Principles of using biophilic design to improve environmental performance.

Biophilic elements			Environmental considerations				W
			Thermal comfort	Air quality	Visual comfort	Auditory comfort	
Direct Experience of Nature	Sunlight	natural lighting					1
	Air & Thermal	Ventilation - air purification - Achieving a temperature reduction					2
	Weather & View	creating an environment that responds to weather changes					3
	Biodiversity & Landscape	Landscape design of animal/plant habitat or biodiversity					4
	Water & Fire	exterior design using water and fire					4
Indirect Experience of Nature	Image of nature	Visual realistic and metaphorical expression of nature					1
	Color & Materials	Natural colors: Finishing design that reflects the characteristics and textures of natural materials					3
	Shapes & Structure	Natural geometric shapes and forms					1
	Artificial lighting & HVAC	Natural light spectrum and HVAC in artificial lighting					3
	Biomimicry	Morphological/material solutions imitating biological characteristics					1
Experience of Space and Place	Transitional Refuge	Relaxing areas with views; connect indoor–outdoor environments					1
	Mobility & Wayfinding	A sense of openness in moving space using natural elements					4
	Complexity Integration space	Complex and integrated design considering biophilic properties per space and layer (i.e., color, pattern, material, etc.)					4
	Place & Community	design based on the characteristics of the local community.					1
	Biophilia & Education	Educational space and signs design for biophilia effects.					1

7. 1. Biophilic design elements under flyovers Table 2.

The following table links the elements of biophilic urban design with the green elements that can be used in city construction, especially roads, paths, and areas under flyovers.

Table 2: Biophilic design elements under flyovers

		green walls	Corridors afforestation	Green streets	Gardens and cultivated areas	green fences	Urban ecological networks
Direct Experience of Nature	Sunlight	Δ	Δ	Δ	Δ	Δ	Δ
	Air & Thermal	Δ	Δ	Δ	Δ	Δ	Δ
	Weather & View	Δ	Δ	Δ	Δ	Δ	Δ
	Biodiversity & Landscape	Δ	Δ	Δ	Δ	Δ	Δ
	Water & Fire						Δ
Indirect Experience of Nature	Image of nature	Δ	Δ	Δ	Δ	Δ	Δ
	Color & Materials	Δ	Δ	Δ	Δ	Δ	Δ
	Shapes & Structure		Δ		Δ	Δ	Δ
	Artificial lighting & HVAC				Δ		Δ
	Biomimicry						Δ
Experience of Space and Place	Transitional Refuge				Δ		Δ
	Mobility & Wayfinding	Δ	Δ	Δ	Δ	Δ	Δ
	Complexity & Integration space	Δ	Δ	Δ	Δ	Δ	Δ
	Place & Community	Δ	Δ	Δ	Δ	Δ	Δ
	Biophilia & Education				Δ		Δ

From the previous two tables, the relationship of biophilic design elements to various environmental considerations is clear, in addition to the most important environmental factors affecting urbanization and their relevance to the principles of biophilic design.As for the following, some of the international experiments that dealt with the areas below the flyovers are analyzed using the green element in them, as the experiments are analyzed according to the used biophilic design elements (direct Experience of Nature-Indirect Experience of Nature -Experience of Space and Place.

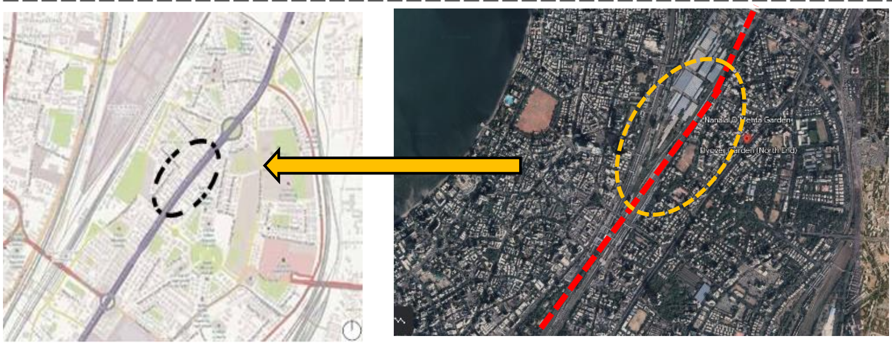
8. Analysis of examples of the use of biophilic design under flyovers

The following examples cover a group of overhead bridges in which the green element and landscaping were used in different ways, and an analysis of their biophilic design elements.

8.1. Mumbai, India: Nanalal D Mehta Garden [12] Fig 5.

-Location: India, it represents the first park under the flyover in Mumbai

-- The areas below the flyovers were developed by residents of Matunga who sought to keep the areas clean and green as their own. - It is a 600-meter walking path in the shape of the Narmada River with plants and grass on both sides [12]



Direct Experience of Nature	-Natural light and ventilation are obtained from the large open sides. -Communicating with nature and green spaces under the flyover and in the surrounding areas, as it contains pleasant paths surrounded by green spaces and cultivated paths, in addition to the surrounding afforestation with high density.		
Indirect Experience of	-The lighting is distributed over the tracks below the overpass, in addition to the lighting in the planted floors along the corridors to achieve a clear vision and a good visual effect. - The colors of the tracks are light and visually comfortable, which has a clear effect on thermal and optical performance.		
Experience of Space and Place	-Providing places to sit and relax around pedestrian paths surrounded by green spaces. -Roads and paths designated for movement are also identified through green spaces.Integrated design under bridges with roads, green spaces, and landscaping in the surrounding areas.		

Green elements: green fences – trees - Corridors and cultivated areas- urban ecological network

Fig 5: Mumbai, India: Nandalal D Mehta Garden experience.

8.2. Vía Verde Vertical Gar0dens in Mexico City, Fig 6.

LOCATION: VÍA VERDE VERTICAL GARDENS – MEXICO CITY, MEXICO

- Mexico on Highway Pillars by Architect Fernando Ortiz of Vía Verde.
- Mexico City has planted "green poles" alongside highways and under flyovers and has turned the poles into green walls to reduce dust and particulate pollutants for residents along inner-city highways.
- Since 2016, the Via Verde project in Mexico City has aimed to transform 1,000 highway poles into vertical gardens. A variety of plants are placed inside felt "pockets" to make the city greener and the air cleaner. The hydroponics system collects rainwater to cover its needs and each garden is equipped with sensors to allow remote monitoring.
- El Periferico is a wide two-story highway that surrounds Mexico City, the first of which dates back more than 50 years and the second was built at the beginning of this century [28], [29].

Direct Experience of Nature	- Green walls purify the air as it reduces dust and pollutants along highways within the city. The vertical gardens are centered on the colonnades along the El Periférico Highway, which circles the city center. [30]. -Vertical gardens help create a natural environment that improves environmental performance and responds to climate change [28]. Works on thermal regulation, as vertical gardens are more effective in reducing the heat island phenomenon.	
Indirect Experience of Nature	- The green wall helped to improve the visual image of the city, in addition to the permeation of natural lighting well under those overpasses with the green walls. - Vertical gardens isolate noise through the intensity of the green element.	 
Experience of Space and Place	- Green spaces and walls work to achieve the necessary calm in urban areas with high densities. Green walls create a sense of environmental presence through colors and textures. - Vía Verde seeks to achieve an integrated environmental design, by linking green walls with the surrounding areas to achieve the environmental benefits of urbanization of the city.	 

- Green elements: green fences – trees – Green Walles

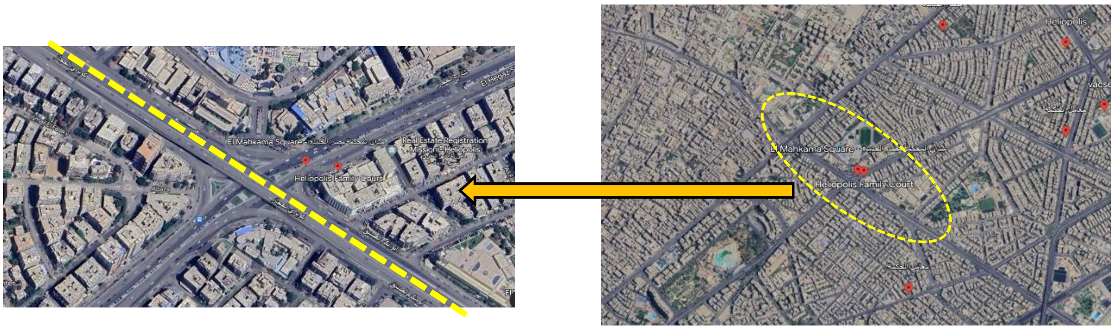
Fig 6: Vía Verde Vertical Gardens in Mexico City experience.

8.3. Heliopoles, Cairo, Egypt. Fig7.

LOCATION: HELIOPOLES, CAIRO, EGYPT

-Overpasses were constructed in Heliopolis to accommodate the traffic density, and the state thought of planting the walls and facades of these bridges to preserve the environment and give beauty to the concrete character. Where the first green spaces were planted on the sides of the El Mahkama square bridge in Heliopolis. [31].

-El Mahkama Square Bridge is currently being planted with 40,000 seedlings on an area of approximately 1,000 square meters, which is equivalent to planting an entire field without leaving spaces, which increases the ability of the seedlings to purify the air.



Direct Experience of Nature	- The planting of bridge walls contributed to preserving the environment, purifying the air, and absorbing carbon dioxide, in addition to dealing with climate change. - It has also been considered that the bridges are not harmful to the bridge body by isolating the walls and preventing water leakage [32].		
Indirect Experience of Nature	- The cladding of agricultural seedlings for the walls and columns of the upper bridge works to achieve a wonderful aesthetic shape, as the color of the bridge turns green. Planting a meter in the walls gives large amounts of greenery, because it does not leave spaces. It also works to reduce noise amid those high densities.		
Experience of Space and Place	- The greening of the walls and columns of the upper bridges works to achieve an integrated design, as the roses and ornamental plants cover the cement bridges and the reinforced walls consisting of sand and gravel, which will add to it a special luster that shines with its bright luster beauty and light in the shape of the bridges and connects them with the surrounding urbanization.		

- Green elements: green colume s – Green Walles

Fig 7: Upper bridges in Heliopolis experience.

The examples of using the green element under the overpasses and the extent of its vital impact on urbanization are analyzed. This research deals with an environmental simulation of one of the upper bridges in the city of Tanta to find out the extent of the impact of the biophilic design of the urbanization on its thermal performance.

9. Case study

9.1. The case study description

The study area was chosen below the flyovers in Alexandria Square and the railroad area in Tanta, and the new overpass in Imam Al-Shafei Street Fig 10. It is one of the most crowded areas with traffic in the city of Tanta, car traffic or pedestrian traffic. This area was selected because it is an area with a high urban density, in addition to being an area close to the main traffic center in the city, which greatly affected the high temperature and harmful oxides in that area. The areas below those overpasses are unplanned, completely unexploited, unclean and lacking the green element, as shown in Fig 8.

Fig 8: Case Study Region in Tanta

The flyover is located at 30° 59 32 longitude and latitude 30 49 36°. The area occupied by these bridges is about 500 meters * 500 meters, linking two areas on both sides of the railways, passing above the railway lines. The case study is one side of this flyover as indicated in Fig 9.

Fig 9: Case Study (google earth)

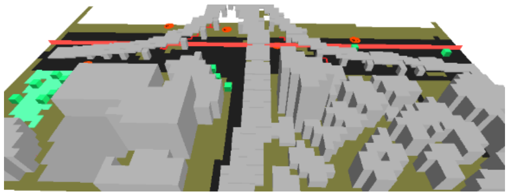
9.2. The case study environmental simulation description with Envi met.

In this paper, the Envi-met microclimate simulation program is employed to simulate the environmental performance of urbanization [33], [34]. This simulation software can facilitate the estimation of the thermal satisfaction of users: the air temperature, and the radiant temperature under flyovers area in the city of Tanta, in its current state and after treatment using biophilic design elements and green spaces. Hence, the effect of these elements on their environmental performance can be measured.

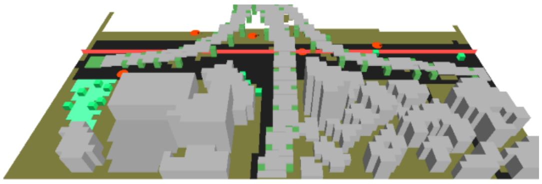
The Envi-met is set to measure the environmental factors (air temperature (Tair)), Mean Radiant Temperature (MRT) and Predicted Mean Vote (PMV)), from 10:00 am until 18:00pm, and the recording takes place at the beginning of each hour, during the solar presence during the summer season (July 2022). PMV is a thermal comfort measure as it is a model to simulate the average pedestrian rate on the thermal performance of the study area scale. The scale ranges from -4 (very cold) to +4 (very hot), while is the thermal balance and thermal comfort check.

The closer the PMV is to zero, the better the balance of energy exchange and thermal comfort. The environmental evaluation is done through three cases, the current situation (Case 1), and after treating the flyovers using the green columns (case 2) and after using biophilic design in the study area (case 3) as shown in Fig 10.

The treatment in case3 consists of placing medium-height trees on both sides of the flyover at regular distances, and shrubs were also placed at the beginning and end of the bridges on both sides. Green areas and grass were also used under the flyover and in some areas on the sides between the trees. A tree fence was also created around the railway fence using medium-height trees with a clear shading area.



Case 1: the current situation



case 2: the case with green flyover s columns

Case 3: the case of biophilic design

Fig 10: 3D Envi -met cases.

This is what Fig11 shows for the study sample after adding biophilic design elements using the Envi-met program.

Then the thermal results of the three cases are compared.

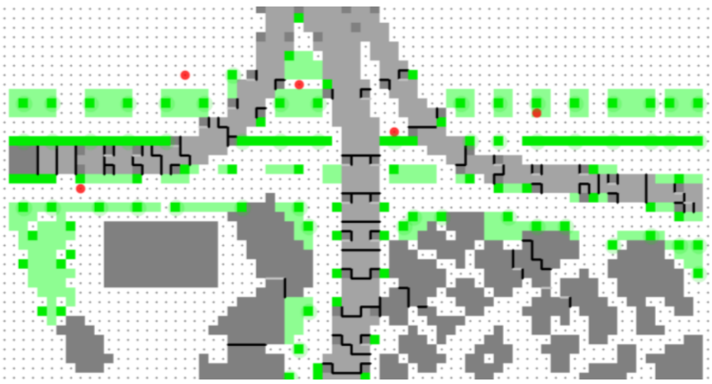


Fig 11: 2D Envi -met case3.

The study sample properties, patterns treatment using biophilic elements, which are used in the ENVI-met program is represented in Table 3.

Table 3: the study sample properties.

Total study area	500* 500 m^2
Grid size	310* 135*30
Data, time of simulation	22-7-2021
	Started simulation at time = 10 am
	Total simulation time in hours = 8 hours
	Save model state each 120 minutes
Boundary conditions	Air temperature C = 28-39 c
	Relative humidity =45%-61%
	Wind speed at inflow border (m/s) = 5
	Wind direction (constant wind direction at inflow) = 270º

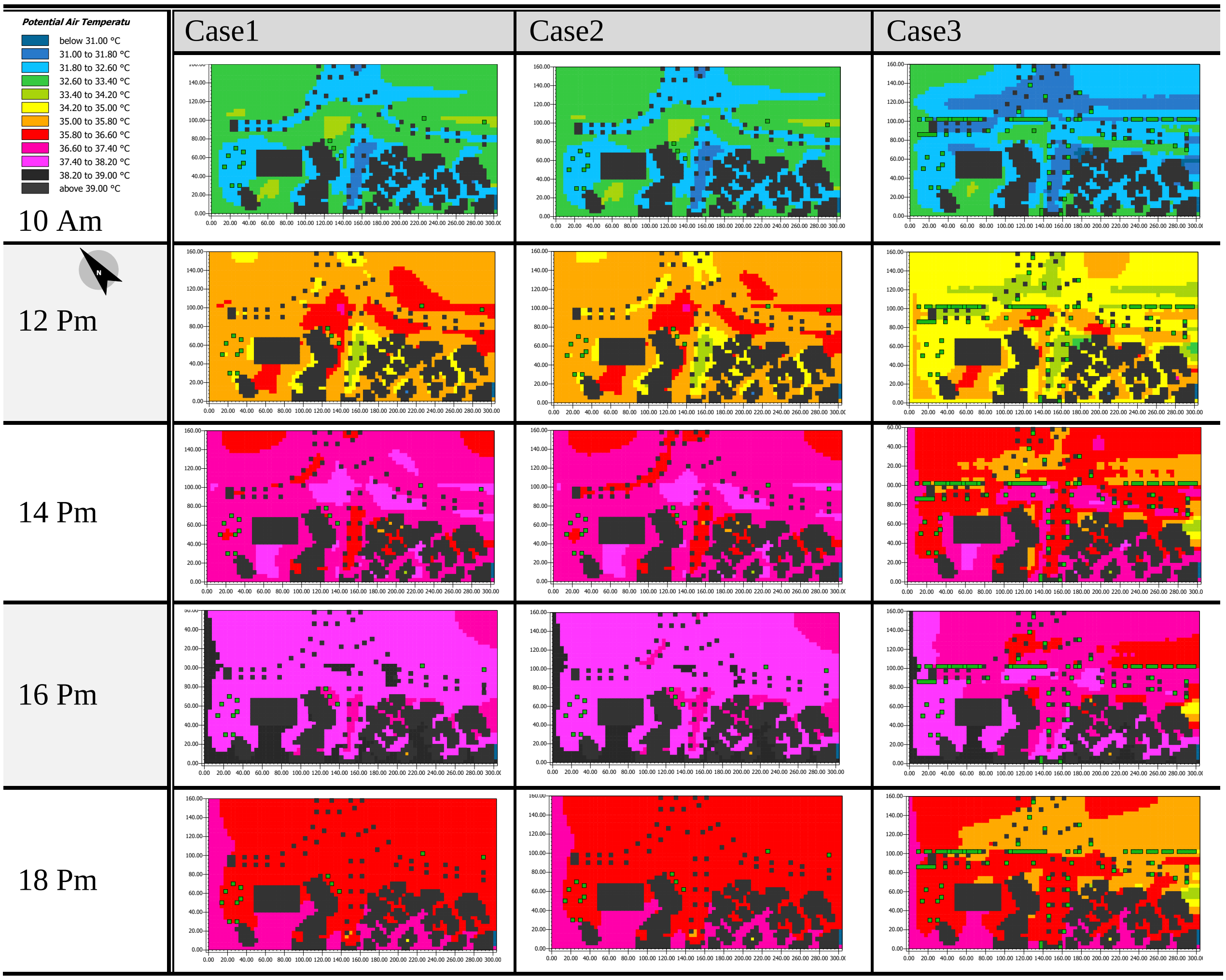
9.3. Simulation Tool Description

ENVI-met is a simulation program that is developed by Michael Burse (ENVI-met 5.1 Manual). It is characterized by several interfaces and each one of them is important for reliable simulation and reading of output data. The software offers three main components that provide the required inputs, while the simulation interface globally checks the data by applying calculation models. It also has 3D modeling capabilities for the local climate, calculating and simulating climate in urban areas with a resolution ranging from 0.5 to 10 meters and as low as 10 seconds time intervals. This program has been used in many studies or evaluations, in terms of bio-meteorological conditions in urban areas. ENVI-met can calculate wind speed and direction in local climate, air temperature, humidity, turbulence, flow of various gases and particles, and dispersion of pollutants, and is able to examine heat exchanges and masses related to surfaces. It enables simulation of surface vegetation, building and atmospheric processes. Furthermore, it can be configured, and its setting parameters modified for the geographical area under study [35].

10. Results & discussion

The following figures show the main results of the simulation in three cases in July, (Case 1) the current situation, (Case 2) after using green bars and (Case 3) after using biophilic design. Air temperature Fig 12, Mean Radiant Temperature (MRT) Fig 13. As for the extent of thermal satisfaction of users (PMV) Fig 14.

10.1. Air temperature



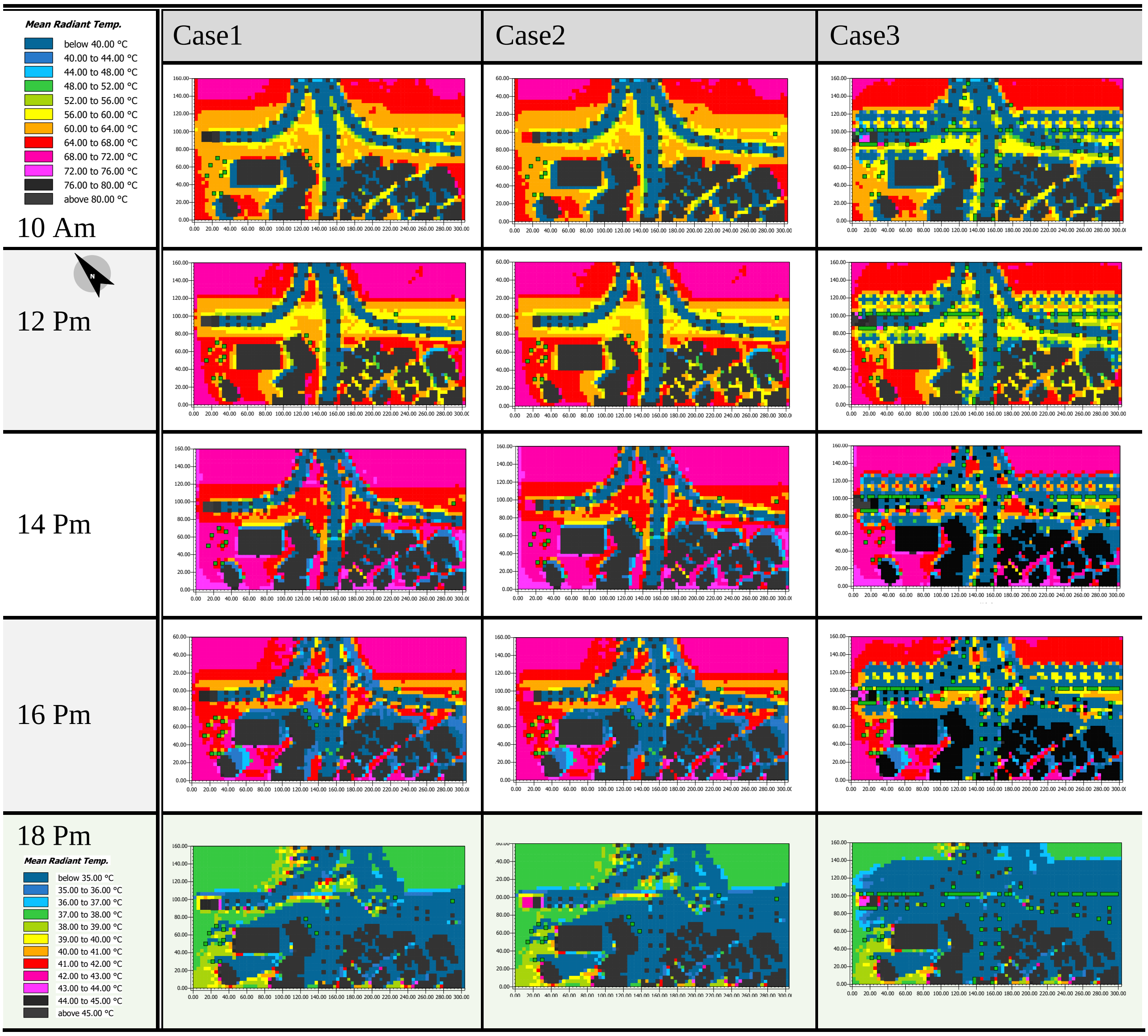
By analyzing the air temperature from 10 am to 18 pm every two hours in the three study cases, the following was found:

-The air temperature decreases slightly in Case2 with the green columns under the bridge compared to Case1 in the current situation. This difference is evident in the right area of the flyover in some simple points, and it reaches about 0.5^{o}c only, especially in the early hours at 10 am and 12 pm.

-In Case 3, which used biophilic design elements such as trees, shrubs, and green spaces, it is evident that the air temperature decreased in July during the measurement hours. It decreased about 1 ° C under the flyover and in the surrounding areas and at the railway fence at 10 am. Meanwhile, it decreased by about 1.5-2^{o}c at 12 pm under and around the flyover in case 3 compared to case 1. The decrease in air temperature is also clearly evident at 14 pm in the case of the biophilic design, where the difference also reaches about 1.5 to 2^{o}c from case 1, which represents the current situation. At 16:00 and 18:00, the air temperature continues to decrease in case 3 compared to case 1 under and around the bridge and at the railway fence, where the decrease reaches about 1-1.5 degrees Celsius.

Fig 12: Air Temperature result

10.2. Mean Radiant Temperature



- By analyzing the mean radiation temperature from 10 am to 18 pm every two hours in the three study cases, the following was found:

- MRT in case1 converges with case 2 in which only the columns were planted, except for some minor points under and around the bridges, which dropped by about 4 ^{o}c, especially at 10 am and 12 pm.

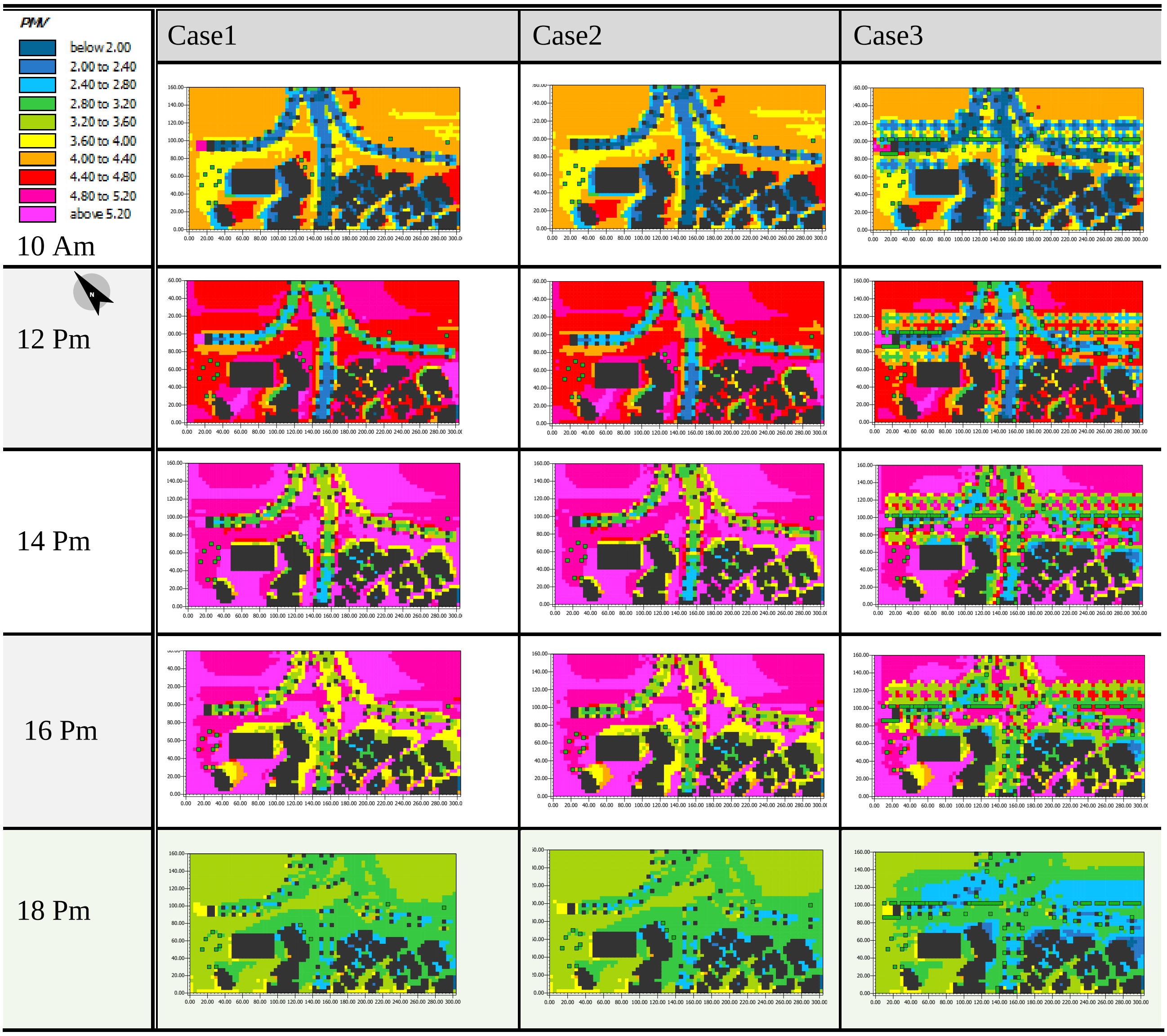
- Case 3, which has a biophilic design for the study sample, has a decrease in the radiation temperature, as it decreased at 10 am from 15 to 20 ^{o}c at the flyover than the current situation, and it decreased by about 8 oc in the surrounding areas. As for 12 pm, it dropped about 15 ^{o}c in the afforestation area and about 6-8 ^{o}c in the surrounding areas.

- As for 14:00 pm, the difference between the MRT in case3, with the biophilic design of the urbanization, and case1, which represents the current situation, reached about 24-28 ^{o}c. At 16:00, the MRT in case 3 decreased by about 20 ^{o}c than in case1.

- At 18:00 pm, the MRT decreased in all cases by about 25 ^{o}c, after the absence of the direct presence of the sun. The decrease was evident in case 3 where the biophilic design influenced the temperature drop in the surroundings.

Fig 13: Mean Radiant Temperature result.

10.3. The thermal comfort PMV

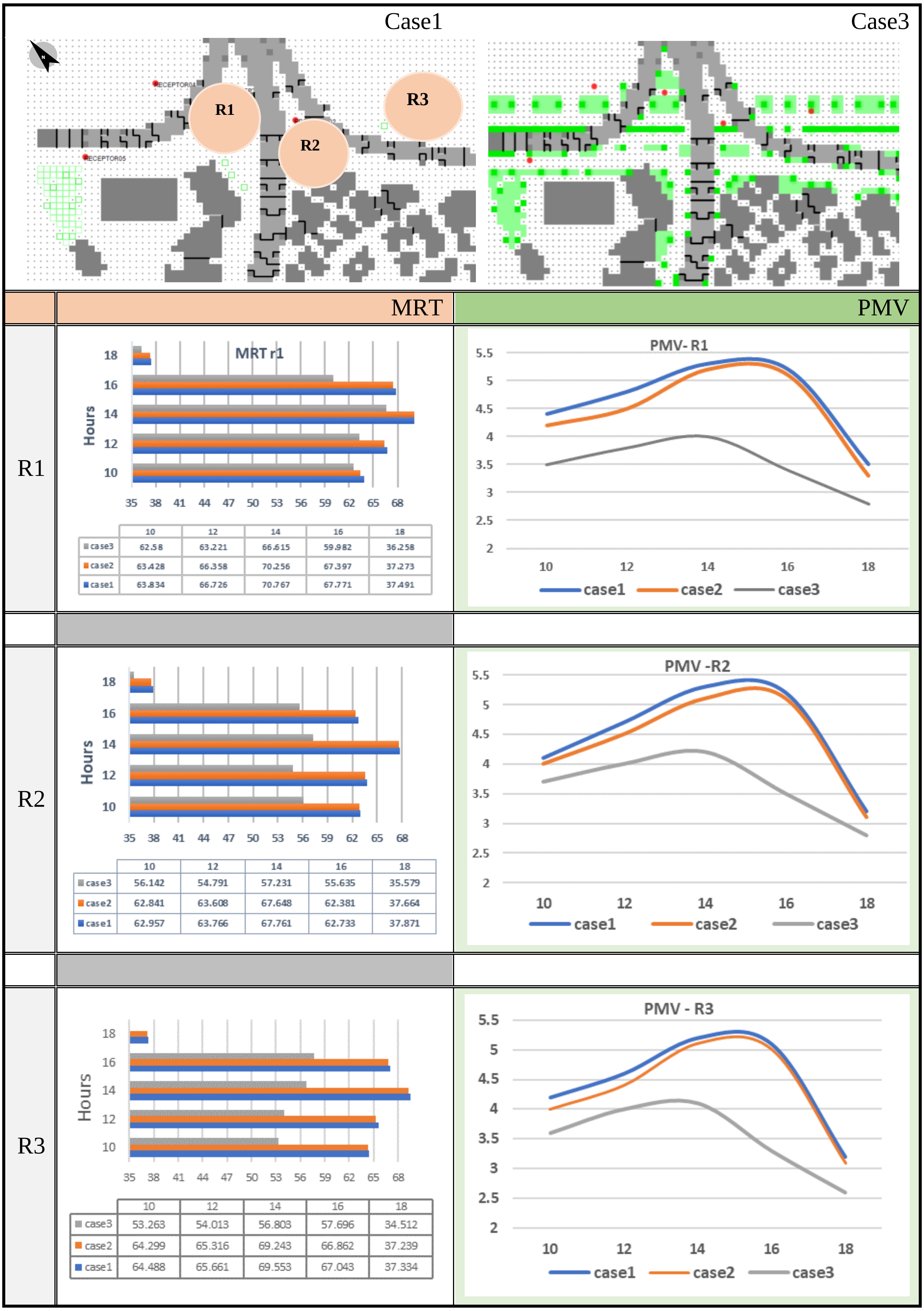


By analyzing the thermal satisfaction rates of users (PMV) from 10 am to 18 pm every two hours in the three study samples, the following was found:

- The highest rates of heat stress during the month of July were from 14 to 16 pm in the three cases, as the PMV value reached more than 5 in case1.
- We noticed in case 2, when cultivating columns only, that the PMV was close in value to case1, except for some areas attached to and under the bridges, in which the PMV value was about 0.4 lower than case1.
- As for case 3, which represents the case in which biophilic design elements were added, pmv was significantly lower than case1, at 10 am it decreased from 4 to 2 and 2.4 in the area of the overpasses and the railway fence. The PMV value also decreased at 12 pm from 4.4 to 2.4, and at 14 pm from 4.8 to 2.8, and at 16 pm the PMV value decreased by about two degrees. It also showed a decrease at 18 pm from 3.2 to 2.4, which confirms the impact of biophilic design elements on the thermal satisfaction of users and the feeling of thermal comfort.

Fig 14: predicted mean vote (PMV) result.

Measurement points were set at the study site in the three cases (in the current situation, case 1, with greening columns only, case 2, and in the case of using afforestation and biophilic design elements, case3). The comparison between them was applied in terms of the amount of radiation temperature and the amount of thermal comfort, as in Fig 15.



R1 (MRT)

	10	12	14	16	18
case3	62.58	63.221	66.615	59.982	36.258
case2	63.428	66.358	70.256	67.397	37.273
case1	63.834	66.726	70.767	67.771	37.491

R2 (MRT)

	10	12	14	16	18
case3	56.142	54.791	57.231	55.635	35.579
case2	62.841	63.608	67.648	62.381	37.664
case1	62.957	63.766	67.761	62.733	37.871

R3 (MRT)

	10	12	14	16	18
case3	53.263	54.013	56.803	57.696	34.512
case2	64.299	65.316	69.243	66.862	37.239
case1	64.488	65.661	69.553	67.043	37.334

Fig 15: Measurement points for comparison between MRT and PMV in the three cases

By analyzing Fig 15, of the thermal performance of the measurement points in the three study cases, the following was found:

Point R1

- At point R1, which is located between the two arms of the upper bridge near the railway fence, the maximum rate of decrease of MRT (the mean radiant temperature) in case 2 with green columns than case1 reached 0.8% at 12 pm, 14 pm and 16 pm. The MRT decreased in case 3 by about 8 degrees, which represents a decrease rate of 12% at 16 pm, representing the largest difference in the radiation temperature during the hours of the day.
- As for the PMV (predicted mean vote) at point R1, the amount of decrease in case 2 from case1 did not exceed 0.2 during daylight hours. Meanwhile, the amount of PMV decreased in case 3 by about 30% compared to case1, especially at 16 o'clock, as it decreased from 5.2 in case1 to 3.5 in case 3, which clearly affects the thermal comfort of users during daylight hours.

Point R2

- At point R2, which is located between the two arms of the bridge on the right side and near the asphalt road, the MRT in case 2 was lower than that of case1 by 0.7% at 14:00 pm and 16:00 pm, which represents a very slight decrease that is not significant. The MRT of case 3 with a biophilic design decreased by more than 10 °C than case1 at 14 o'clock, which represents a decrease rate of about 16% in the radiative temperature, which clearly affects the temperature of the region.
- As for PMV, the rate of decrease in case 2 with green walls compared to case 1 is about 5% only. the amount of PMV in Case3 with a biophilic design decreased significantly from case1, as it reached a maximum decrease at 16 pm from 5.2 to 3.5, which represents a decrease of 32.5%, which confirms the increase in the sense of thermal satisfaction for users when using the natural elements of the biophilic design.

Point R3

- At point R3, which is located between the right arm of the bridge and the railway fence, we found that the MRT had a maximum decrease, in Case 2 than in Case1, by 0.5% at 14:00. While the MRT in case 3 decreased by more than 13 °C at 14 pm than in case1, representing a decrease of about 18% in the case of the biophilic design.
- As for the PMV at R3 point, its rate of decrease in case 2 compared to case 1 was only about 5%. While the decrease in PMV in Case3 with a biophilic design compared to Case1, reached its maximum at 16 pm from 5.1 to 3.3, representing more than 35%, which affects the thermal comfort of users.

Hence, the positive effect of using the natural elements of biophilic design is evident to improve thermal performance under flyovers and their surrounding areas.

11. Conclusion

- The spaces under the overpasses are inevitable spaces, which must be used positively to achieve integration and interdependence with the surrounding environment, in terms of visual coherence and good environmental performance for urbanization.

- The biophilic design of the urbanization, which represents the connection with the natural environment, the green element, and the use of green infrastructure in the roads, is an important mechanism for achieving thermal, visual, and auditory comfort for users, especially under flyovers and their surrounding areas.

- The research concluded through the case study in the upper bridges area in the city of Tanta using the environmental simulation program Envi met, that the areas under the flyovers in their current condition do not achieve thermal comfort for users, as the air temperature in summer in the thermal peak hours reaches more than 38^{o}c. While the MRT more than 70^{o}c.

- The greening of the columns of the overhead bridges works as a good aesthetic and visual element, but it has a weak effect on the environmental performance. It reduces PMV by only 5% to get close to thermal comfort rates. Also, its effect to reduce the MRT (mean radiant temperature) does not exceed 1% only, which confirms that planting the columns of the upper flyovers only do not clearly affect the thermal performance of the areas of the upper flyovers.

- The research also concluded that the biophilic design of the overpasses and railway fences, from planting trees and green spaces and using green fences for railways where communication in green infrastructure elements, works to reduce the air temperature by more than a full degree Celsius during daylight hours in summer. It also works to reduce the amount of PMV by about 35% from its current state during the hours of solar presence to achieve thermal satisfaction for users.

- The biophilic design of the study sample also worked to reduce the radiation temperature by 18%-20% from the current state of urbanization, which achieves good environmental performance and emphasizes the role of natural biophilic design elements in the design of overpass areas in cities.

Recommendations

- More focus and attention on biophilic design elements within the construction of existing cities to benefit from their environmental impact, whether thermally or visually, or to obtain air quality.
- The research recommends the necessity of good design of the areas under and around the overhead bridges and the use of the green element and landscaping to create environmentally friendly spaces in these inevitable areas.
- The research recommends not only greening bridge columns and their walls, but also using green areas and trees to improve environmental performance to achieve thermal comfort in those areas and under them.

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التصميم البيوفيلي كأداة لتعزيز الأداء البيئي تحت الجسور العلوية

الملخص

نظراً لزيادة عدد السكان والحركة بين المدن، زادت عدد الجسور لتسهيل التنقل بين المناطق المختلفة في المدن مما أدى إلى ارتفاع حركة السيارات. ونتيجة لذلك، زادت الانبعاثات الكربونية والتلوث، مما أثر على درجة حرارة الهواء وجودته في المناطق الحضرية.

لذا فإن هذا البحث يركز على دراسة كيفية تحسين الأداء البيئي تحت الجسور العلوية في المدن. حيث دراسة اليه تحقيق هدف البحث من خلال التصميم البيوفيلي الذي يعمل على حيوية العمران والاندماج مع الطبيعة، كما يعزز البنية التحتية الخضراء.

يتناول هذا البحث دراسة الجسور وخصائصها والمعايير اللازمة للحصول على مناطق فعالة أسفلها، والتصميم البيوفيلي (الحيوي) للعمران، وأسس ومعايير استخدامه لتحسين الأداء البيئي تحت مناطق الجسور العلوية، مع تحليل أمثلة على التعامل الفعال مع الجسور.

قام البحث على بدراسة حالة للمناطق الواقعة تحت الجسور بميدان الإسكندرية بمدينة طنطا وتحليلها قبل وبعد المعالجة باستخدام التصميم البيوفيلي وذلك باستخدام برنامج المحاكاة البيئيةEnvi-met .

وقد توصل البحث انه يمكن للتصميم المقترح باستخدام عناصر البيوفيليا أن يقلل من قيمة PMVبحوالي 35% من حالتها الحالية خلال ساعات التواجد الشمسي ويحقق الرضا الحراري للأشخاص.

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