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The Impact of Wind Movement on Providing Thermal Comfort in Urban Design

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Abstract The wind movement is a crucial factor in enhancing thermal comfort, forming an essential part towards friendly and sustainable urban environment. Air movement, as a prominent climatic factor, reduces heat stress with improving ventilation quality. Effective natural ventilation and heat stress mitigation can be achieved by orientation, planning and shaping the urban blocks in urban environments. Air movement represents the most important element in improving environmental adaptation, as the rapid airflow reaching buildings can significantly reduce their temperature. Site planning requires precise knowledge of the main wind directions and speeds. The research utilized the ENVI-met Models program for modeling urban environments and predicting thermal effects in the built environment. This program plays a crucial role in understanding and analyzing environmental conditions and their impact on thermal comfort. The research addressed the knowledge gap and lack of local studies in highlighting the role of wind movement in enhancing thermal comfort in urban environments using ENVI-met Models. The research aimed to provide specific knowledge in measuring wind movement and its role in enhancing thermal comfort in urban environments using the program. The research hypothesized that analyzing and modeling wind movement with ENVI-met Models can effectively contribute to understanding and improving thermal comfort in urban environments. One of the key findings is that studying the impact of wind movement with this program is essential for providing scientific and technical foundations to improve urban design and enhance thermal comfort in urban areas, promoting sustainability and environmental quality in cities

Keywords: Wind movement, thermal comfort, ENVI-met Models program, sustainable urban environment.

1- Introduction

Thermal comfort is one of the key factors that significantly impact the quality of life in urban environments. Urban design, with its architectural and urban details, serves not only as a means to achieve beauty and practical functions but also to ensure a comfortable and suitable environment for

residents. In this context, the influence of wind movement plays a prominent role in redefining the traditional concept of thermal comfort in urban design.
Changes in climate patterns are accelerating, and urban growth is multiplying, making it imperative to shed light on how urban design can benefit from wind movement to enhance human thermal comfort. Within this context, understanding the impact of wind movement and its relationship to providing thermal comfort is crucial in urban environment design. This enables the ability to incorporate effective strategies to improve air flow and guide winds in ways that enhance thermal comfort for residents.
This study addresses the impact of wind movement as a major variable in urban environment design and its effect on thermal comfort. The research will examine the techniques and strategies used to improve wind movement in the urban environment and how they can contribute to providing optimal thermal comfort for residents. The study will investigate the impact of wind movement in delivering effective thermal comfort, focusing on how to integrate this factor into the urban design process by highlighting the methods and technologies used to analyze wind movement and apply it in the context of urban design.

2- Thermal comfort indices

The psychological state in which people feel relief from their thermal surroundings is referred to as "human thermal comfort". [1]
The mental condition in which one feels satisfied by a pleasant thermal environment is known as human thermal comfort. The Mean Radiant Temperature (TMRT) is the main element influencing human thermal comfort in outdoor urban environments. .[2]. TMRT is defined as the total of short-wave and long-wave radiation fluxes absorbed by the human body, influencing energy balance and thermal comfort. [3]. The Predicted Mean Vote (PMV) serves as a key index for assessing outdoor thermal comfort, relying on factors such as heat balance and perceived temperature parameters [4]. Mean radiant temperature has been shown to have a substantial impact on important thermal indices such as the Predicted Mean Vote (PMV), which is based on human energy balance models.[5]

3. Passive Cooling System

The term "Passive" emerged during World War II by the United States' space agency (NASA) to describe air control tools on Earth without use mechanical control devices nor mechanical generation tools, as reported in "Building System Design" magazine in 1972. The focus at that time was on heating rather than cooling as the United States and Europe in contrast to the Arab world and hot arid regions, specifically in Iraq. Attention initially focused on single buildings before shifting to multi-story buildings, various and several studies on self-heating and cooling, it became possible to reduce energy consumption required for heating and cooling by up to 68% in each case. [6]
In architecture, passive design is ensuring that the building's shell and its spaces efficiently respond to the local climate and site circumstances to maintain thermal comfort for occupants with low usage of supplemental energy. [7]
The performance of passive systems is heavily reliant on natural and environmental factors such as sunlight, wind, soil, and water. As a result, it is critical to research and assess how passive systems interact with these natural components, as well as their relationship to the construction site. As a result, incorporating passive cooling systems into the design process is critical, as their performance requirements are influenced by factors such as orientation, elevation, materials, form, and various architectural features' characteristics. [8]
The world's shift towards using this system was a result of the 1973 energy crisis, which prompted significant efforts to seek energy alternatives. Experiments have confirmed the system's effectiveness and efficiency, highlighting its remarkable advantages, which can be summarized as follows: Self-cooling systems are straightforward and uncomplicated when compared to other systems, as they contain few or no moving parts. This is what makes them cost-effective.

1- Self-cooling systems are inherently sustainable as their lifespan is typically aligned with the need for habitation. This is because they rely on locally available traditional building materials, reducing the requirement for complex and costly expert.
2- A straightforward system in terms of operation and maintenance, with low operating and maintenance costs.
3- It conserves fuel due to its minimal or infrequent usage, as it relies on natural mechanics for load, conveyance, evaporation, and radiation.
4- It doesn't require pipelines and transmission lines; hence it doesn't cause environmental pollution.
5- The system's required additions provide additional appeal to the building, as they utilize south-facing glazed spaces that serve multiple purposes such as plant cultivation or outdoor workspaces, thereby reducing costs when measured by their multi-functionality.
6- Furthermore, in addition to what was mentioned above, the passive system relies on building design that leverages the local climate's advantages and can seal itself off from adverse weather conditions. This necessitates a greater architectural specificity to harness the energy-saving opportunities presented by the site-specific climate.

Moreover, it evokes the image of traditional buildings, which have proven their efficiency and adaptability to environmental conditions over the years. [9]

4. Passive solar concepts

1. Collect and absorb maximum solar radiation during the daytime.
2. Store the accumulated heat from sunlight during the daytime.
3. Emit this heat into the building during the night-time.
4. Fully insulate the building to maximize heat retention, as illustrated in the Figure (1).
5. Provide acceptable levels of thermal comfort through site planning and proper building orientation.
6. Minimize the environmental impact by reducing greenhouse gas emissions.
7. Select appropriate window openings, ventilation, and shading locations.
8. Strive for energy efficiency, along with self-sufficiency from renewable energy sources.
9. Utilize insulating materials.
10. Design interior rooms and spaces.
11. Incorporate thermal mass [10]

5- Passive Cooling Actions

Understanding the sources of heat gain that affect thermal comfort in a structure is critical for deciding the appropriate measures to avoid excessive heat acquisition, slow down the heating process to remove unwanted heat, or store cold air. There are four passive cooling measures: [11]

1. Keep the cool mass of air inside the building envelope. This measure is defined as keeping cold air away from direct heat gain to supply the building with cool air, or cooling the air before it enters the interior spaces.
2. 2. Avoid heat gain from direct external sun radiation. This measure is accomplished through design considerations and architectural elements. Avoidance can be achieved by shading windows and glass spaces, planning landscapes, producing self-shading shapes, and addressing the hues and reflectivity of outside surfaces.
3. Remove any acquired heat from internal or external sources. This can be accomplished by controlled ventilation, which includes elements such as wind towers, earth tunnels, and windows to suit ventilation needs. This step is required to reduce some undesirable heat that cannot be avoided or delayed.
4. Reduce the rate at which heat is transferred from the external environment via the building envelope. This strategy is implemented utilizing strategies such as efficient insulation or double glazing. [12]

6. Architectural Principles of Passive Solar

The passive cooling design relies on two fundamental principles: preventing direct heat gain and rejecting unwanted heat. The prevention of direct heat gain is based on three design considerations [13].

Firstly: The Site

a. Selecting the appropriate site.
b. Proper orientation.
c. Utilizing landscaping and hardscape design.
d. Adopting the principle of grounded masses in self-cooling.
e. Considerations of the prevailing climate.

Secondly: Architectural Elements

a. The size, volume, and location of windows and doors (affect the building's exposure to openness and closure).
b. The ratio of exterior surface area to volume (S/V).
c. Using smart screens and masks.
d. Horizontal and vertical louvers for shading.

Thirdly: Building Materials and Their Environmental Characteristics

a. Using insulation materials in their appropriate places.
b. Using smart glass.
c, Using mass for thermal protection.
d. The type of materials and their thermal and radiate properties.
e. The texture and thermal absorptivity.

As for the principle of rejecting unwanted heat, it is based on three considerations:

Firstly: Direct loss.
Secondly: Indirect loss.
Thirdly: Isolated loss.

7. Passive design through the use of wind and natural ventilation.

Wind movement is one of the most crucial climatic factors that assist in reducing the heat load on the urban environment, and good ventilation can be achieved through the location and orientation of buildings within the urban environment. The massing of urban buildings and their external envelope play a significant role in obtaining natural ventilation [14].

The traditional architectural approaches have paid significant attention to the role of ventilation in the natural cooling process, treating it wisely and with precise knowledge. Even though the rules, as seen by Hassan Fathi, shift in independent molds, they have inspired global thinking in terms of conditioning and the environment by embodying the negatives and strengthening the positives. An example of this is the use of architectural wind-catcher forms by Paul Rudolph in the design of the Architecture Building at Yale University [15]. These treatments came after Arab architect benefited from the characteristics of airflow movement through their precise knowledge of aerodynamics which are based on two main principles:

The first principle is based on the variation in air pressure induced by variations in wind velocity. This causes airflow to move from a high-pressure area to a low-pressure area., based on Venturi action derived primarily from the Bernoulli effect which essentially states that the pressure of a moving fluid decreases as its speed increases.

The other principle is based on the flow of air by convection, which occurs when air is heated and rises, causing warmer air to be replaced by cooler air. This process can result in the stack effect, which has become a core basis for many intelligent or natural cooling solutions in modern buildings. When warm air rises, it must be replaced by cooler air from its surroundings. With a continuous heat source, a steady airflow is formed. [16]

Air movement is the most crucial aspect of passive conditioning, as air movement, with a speed of up to 2.3 m/h., can reduce the building's temperature by 5 degrees Fo. Site planning requires information about prevailing wind direction and speed. Climate solutions in traditional architecture within cities and buildings have relied on these principles to create a natural conditioning system. It starts with open public squares, proceeds through various-sized internal courtyards, and extends to the nature of finishes, planting availability, water fountains, and more. These various elements, along with their different levels of sun exposure, create different pressure zones between them, resulting in natural air currents through shaded, winding narrow alleys leading towards sunny courtyards, thereby generating natural air movement [17].

8. Cooling using the principle of passive shading

The application of passive cooling strategies relies on the interactions between the building and its surroundings. Before implementing these bioclimatic strategic techniques, it must be ensured that they are suitable and compatible with the natural climate conditions. This is referred to as "self-passive cooling." Passive cooling can serve as an alternative to mechanical cooling, which requires complex cooling systems. By applying passive cooling strategies in buildings, it is possible to eliminate or at least reduce the size and cost of equipment [18].

Passive cooling includes natural processes, heat dissipation techniques, heat protection, and relevant design strategies. It is a natural method that does not involve the input of any other forms of energy apart from renewable energy sources or complementary mechanical systems. Passive cooling is closely related to the thermal comfort of occupants. Some passive cooling techniques do not remove the cooling loads from the building but rather expand the boundaries of the allowable thermal comfort for occupants in a specific space.

A sustainable cooling system includes passive cooling as well as other applications. More importantly, all these systems must be innovative, meaning they should be suitable for various climatic conditions. The building's location and the design of its interior spaces determine the extent of exposure to sunlight, daylight, and wind for the outdoor spaces. Additionally, the building's shape controls both the processes of heat loss and gain by altering the ratio of the exposed area to the volume. The primary goal is to reduce heat gain during the summer due to high external temperatures and direct sunlight. Thermal insulation can also reduce the heat load resulting from the building materials [19].

In the summer, it reduces heat gain, and in the winter, it reduces heat loss. The concept of heat loss can help create a balance in the energy exchange between the interior and the exterior.

Heat gain can come from both internal and external sources. Human activities, industrial lighting, equipment, and technologies utilized by occupants all contribute to internal heat gain, whereas exterior heat gain is caused by the building's contact with the surrounding environment. Heat gain or loss is made up of four features:

First, the heat gain caused by solar radiation flowing through non-transparent outer materials and heating the inside spaces with the greenhouse effect. (*the global greenhouse phenomenon is also known as global warming or climate change, and greenhouse gases, which are natural phenomena that occur due to the retention of gases emitted from the Earth's surface, leading to an increase in the Earth's temperature. Several gases play an active role in causing this phenomenon, the most important of which are carbon dioxide, water vapor, methane, ozone, nitrous oxide, and finally, chlorofluorocarbon compounds or CFCs.).

Secondly, Heat gain is caused by direct sunlight entering through windows and translucent surfaces into interior rooms.

Thirdly, the heat gain is caused by the conduction between the building envelope and its surroundings.

Fourthly, the heat gain is caused by the conduction between the building envelope and its surroundings, as shown in Figure (2).

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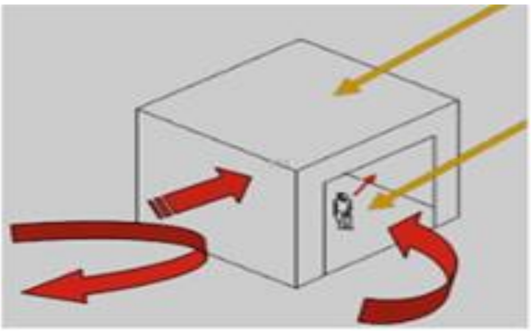


Figure 2. Building interaction with

These systems are designed for hot climates, and some of them can be used for cold climates. Heat re-radiated has different wavelengths and cannot easily pass through glass. In most climates, trapped radiated heat is desirable for heating during the winter season, but it should be avoided during the summer season. Shading the walls and surfaces is of utmost importance to reduce heat gain in the summer, especially if they are dark in colour and lightweight. As for passive cooling, there are several important considerations for it, which are: [20]

1. Orientation of the openings, which should be shaded, as south-facing windows can be easily shaded since the angle of the sunlight is high.
2. Using plants for shading the building to reduce glare and unwanted heat gain, as well as shading the walls and roofs for reducing heat gain in the summer.
3. The shading used in the structure of the building or outdoor spaces differs from cooling inside the building; it reduces the temperature by about 5o to 10o. The solution lies in combining various cooling systems like evaporative cooling through water or trees, geothermal cooling, or ventilation cooling, among others, which help in creating passive cooling systems. As for shading patterns, they come in various types, including:

* Shading through the stacked building blocks: These types of shading are essential for cities with hot climates. The architectural design concept starts with the idea of providing shade to protect the building envelope from high temperatures and providing a source of cooling that covers all architectural creativity concepts, as shown in the Figure (3). [21]

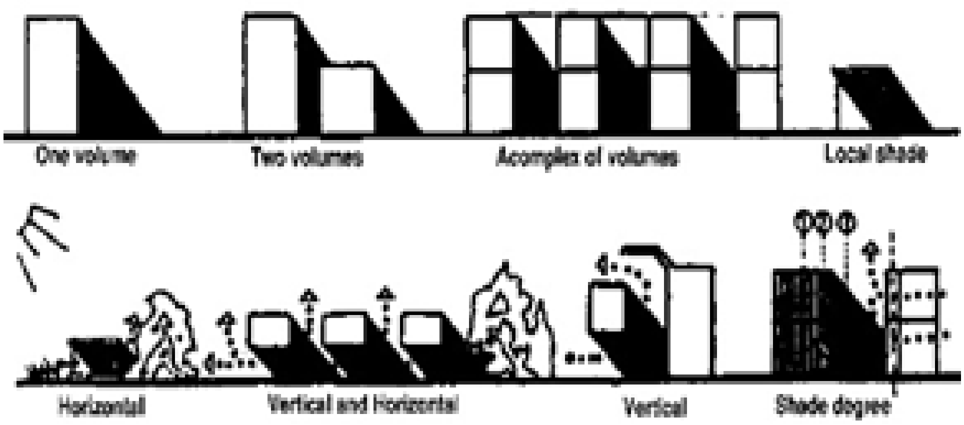


Figure 3. Different types of shading for bioclimatic buildings in hot climates [18]

It can be achieved by minimizing the external wall surface area exposed to heat loads. Therefore, the first step is to provide an efficient passive shading system by creating various volumes with varying heights that generate shades contributing to cooling the building, as shown in Figure (4).

Figure 4. Shading form of the integral solutions [18]

Shading in the central courtyard.
Shading the space with a protective space.
Shading with adjacent natural elements.

9- Passive cooling techniques in urban environments.
Currently, 50% of the world's population lives in cities, with this figure anticipated to rise to 70% by 2050. The primary causes of this fast urban growth are economic and social considerations. Cities provide opportunities such as work, education, security, and social services. However, these cities require a large quantity of energy to sustain such activity. Urban regions account for over two-thirds of total global energy use and 70% of greenhouse gas emissions. [22]
A crucial prerequisite for the future is the strategy that attempts to lower the amount of excess energy consumed and the adverse impacts of mechanical air conditioning in metropolitan areas. Here are some potential remedies for this:
1. Tailoring building conditioning to the unique urban environmental conditions to effectively integrate energy to handle shifts and drastic modifications in the urban environment's radiative, thermal, humidity, and airflow dynamics. This involves optimizing thermal comfort and lowering cooling energy consumption through the use of passive cooling systems.
2. Improving the urban microclimate to counteract the effects of temperature rise, heat islands, and the consequent rise in building cooling requirements. This could entail, among other things, making better use of green spaces, utilizing cooling ponds to disperse heat, and carefully designing urban canopies. [23]
The climatic conditions of hot arid regions have led to the creation of organic compact building clusters characterized by high housing density and shaded narrow streets. Eco-friendly designs are preferred, aiming to minimize energy consumption for cooling purposes. The organic compact clustering aligns with ecological principles. The diversity within these clusters helps maintain a balance between energy inputs and outputs, involving recycling, waste reduction, pollution control, and taking a holistic view of the city as part of nature [24]. Traditional cities with organic compact clustering have adapted and

integrated with the natural environment, utilizing natural energy sources for passive building conditioning. This clustering reduces the exposure of surfaces to solar radiation and other heat loads.

9.1 Urban form and passive envelope

A tight, layered structure that blocks heat loss in the winter and gain in the summer characterizes traditional urban design. This design decreases the energy required for heating and cooling. In hot regions, structures stretching along the east-west axis provide better shade for east and west-facing walls. These interconnected buildings shade each other, thereby reducing cooling needs in the summer.

Architects have emphasized the importance of designing buildings that are self-conditioned rather than relying on fossil fuel energy. However, little thought has been given to the idea of adopting this technique to entire communities and urban centers. Designing a self-contained building differs significantly from developing densely populated urban regions in which each building is heated and cooled solely with natural energy sources. It is critical to research and apply this on a citywide basis. Recent research, combining historical knowledge with quick computer techniques, demonstrates that self-conditioned solar cities are a plausible alternative, allowing for high population density while remaining environmentally sustainable. [25]

As previously said, passive design does not rely on any new technologies. In reality, it has been around for thousands of years. Buildings have been designed to be climate-appropriate by taking into account their location, orientation, shape, and building materials. This has resulted in a variety of local building systems that have proven successful around the world. In contrast, most modern structures have a similar appearance independent of location. They are composed of the same materials, driven by trends rather than climate, and are frequently sited and oriented arbitrarily, with no concern for sun angles or prevailing wind conditions.

Modern cities, which rely heavily on fossil fuels, have become uninhabitable for the majority of the year. They're either too hot, too cold, or too dark. Previously, it was simple to align homes to harness the sun's energy. However, in urban contexts, building orientation is heavily influenced by street layouts, and one building can readily overshadow another. Tall structures impede the gathering of solar energy, making passive architecture less viable [21]. This does not imply that passive solar architecture cannot be applied to entire cities. It simply demands more advanced preparation. Solar access to particular structures is regulated by only four factors: latitude (the distance north or south of the equator), slope, building shape, and orientation.

In urban areas, passive solar design is based on seven factors: the four previously mentioned, as well as building height, street width, and street orientation. These factors also influence ventilation in metropolitan areas, with latitude lines giving way to prevailing wind conditions.

10- The environmental analysis of the traditional fabric.

Traditional architecture in arid regions is characterized by its closeness to the harsh surrounding nature. It features a distinctive urban fabric known for its compactness, narrow shaded alleyways, and small courtyards within the urban texture. Urban experiences in arid regions show that this compact urban form is a response to climate stresses. The human need to adapt to the dry climate leads to the development of these compact urban forms, helping to create a local, moderate microclimate. The narrow streets and alleyways block sunlight and sandstorms and trap cold air, resulting in a moderate breeze. [26]

Urban compactness can be achieved through various means, and population density is a common measure that is directly associated with an environmentally friendly orientation, often referred to as sustainability. Studies have shown that cities with lower density (5-10 times less) result in approximately five times more energy consumption. Compact urban fabrics aim to match the urban dimensions, particularly the relationship between building height and street width, known as the height-to-width ratio in urban planning. This ratio is related to a climate phenomenon called heat

islands, which cause air temperatures to rise above the city compared to its surrounding suburbs. Compact urban planning significantly reduces the heat island effect compared to the impact of cooling loads. [27]
Certainly, climate is a dominant factor in urban planning for cities, and this is why you observe a regularity in urban fabric in all arid regions. Urban planning in these areas typically exhibits two main characteristics:
The presence of relatively wide courtyards, open spaces, and inner gardens often dominates the overall city planning in these areas. Typically, the urban fabric in these regions includes inner courtyards that function as reservoirs for cool, fresh air. This design is found in many organic and compact cities, as shown in Figure (5). This design is found in many organic and compact cities, as shown in the illustration.

Figure 5. The organic compact system of Baghdad city

Climate conditions have influenced the formation of the organic urban fabric in the city to protect pedestrians from the sun's heat and provide the necessary shade through the use of narrow streets, vertical masses and cantilevers. In addition to the house’s cohesion, this has reduced the wall areas exposed to direct sunlight in the summer and the outside cold in the winter. As a result, it helps keep indoor areas cool in the summer and warm in the winter. The existence of urban gaps in the city's fabric has also aided air flow via the nearby alleyways. Furthermore, the urban voids created a flow of air as they connect the spaces on the first floor, which are suspended above the alley, casting another layer of shade and thus promoting air circulation. [28]
The direct application of the cohesion concept is one of the important factors in achieving ecological balance, which involves reducing pollution, mitigate the heat island effect. and considering the city as part of nature. Cohesion has a strong relationship with the concept of passive adaptation, and organic shaping relates to cohesion principles through the physical relationship of buildings with the ground, the materials used, and urban shaping that is in harmony with the environment. One of the advantages of cohesion is shaping based on reducing energy requirements through efficient land use [29].
The emergence of the snaky road network in traditional houses has resulted in solutions to many climate-related problems, such as:
1. Impeding the movement of dust-laden winds and reducing their speed, thus retaining the cool air that accumulates in the streets during the night for extended periods during the day, which helps in cooling the indoor spaces.
2. Reducing the exposure of the external building surfaces to scorching sunlight.

3. Protect pedestrians from sunlight as they move between passageways and streets by shading the passageways due to their narrowness, curvatures, and the protrusions of the first floor that extend over the alley.

11- Passive Climate Control Techniques in Traditional Architecture

Traditional architecture has responded to harsh environmental conditions by:
1. Utilizing the topography of the land for residential purposes.
2. Using plant elements such as trees and gardens.
3. Configuring a compact urban layout with narrow traffic paths to allow shading building facades, providing shade for pedestrians, blocking cold winds, and controlling local air movement.

Openness of buildings towards the interior by organizing interior spaces around a central courtyard, reducing the exposed external area, and creating a thoughtful, seamless system between the interior courtyards of the urban fabric [30].

12- Techniques of Passive Adaptation on Urban-Level

The structure of the traditional Arab city, formed in arid and semi-arid climates, is characterized by narrow streets and sometimes covered alleyways to provide shade for its refreshing and climatically adapted spaces that are integrated with the local architectural style. It's a cohesive fabric that allows the retention of the cool air stored during the night due to nocturnal radiation towards the sky's dome. This cool air remains stagnant in the urban space for around 3-4 hours after sunrise, gradually increasing its temperature. Additionally, the cohesion leads to a reduction in heat gain due to exposing a smaller surface area of the urban rooftops to the outside, while also acting as a barrier against hot winds carrying dust.

13- Urban shadow

The traditional urban fabric is part of a solar protection system, housing the maximum number of horizontal residential units that are open towards the interior, arranged in a way that minimizes the sun-exposed areas. This urban form is characterized by narrow streets, ensuring shading of the urban facades, and depending on their orientation, allows for the utilization of sunlight in the winter. The degree of street enclosure and urban space (the relationship between street width and the height of surrounding buildings) has also been employed for protection against cold winter winds and hot summer winds [12].

The narrow and winding arteries of movement reduce the hours of direct sunlight on the facades and prevent the winds from sweeping away the cold air that accumulates at night. Sometimes, the movement pathways are roofed to ensure continuous shading throughout the day, allowing pedestrians to navigate within the urban fabric. The reduced surface area of urban rooftops exposed to the exterior in the cohesive urban fabric implies a decrease in the surface heat exchange between the interior and exterior, thus conserving energy within the indoor environment, away from the harsh external climate [31].

14- Coherent voids in the conventional urban fabric.

The coherent void is an integrated system made up of urban courtyards, narrow streets, and inner courtyards that work together to regulate the local climate for the entire urban fabric and individual structures. Arab architecture used two ideas to ensure natural circulation inside the connected and unified void of the old Arab metropolis. The first concept is based on the fluctuation in air pressure caused by differences in wind speed, which results in the movement of air from high-pressure to low-pressure places. The second concept is based on air movement influenced by the load caused by the heating and rising of air, forcing the entry of cooler air in its place. [3]

15- The coherent void and its role in passive adaptation

The open urban spaces in the traditional fabric are distinguished by their appropriate locations, proportions, and integration into the urban environment's massing. They are regarded as the best and most natural structures and can be used to manage energy and natural resource consumption. The public squares in the traditional urban fabric include green areas and water features, while others are paved and dedicated to social events.. These squares come in various sizes and shapes, some shaded and some sunny. This spatial variety naturally creates a clear difference in air pressure between different spaces, imposing the principles of temperature variation.

This variation between spaces leads to the flow of air through the narrow, shaded alleyways, creating an airflow throughout the traditional urban fabric [28]. The alleys are linear pathways that narrow in some parts of the urban fabric and widen irregularly in other parts, creating a spacious environment with varying high-pressure areas of cool, shaded air. This air is directed towards the residential levels through smart joints designed by Arab architects. These joints enhance the efficiency of air movement, starting from the residential-level gates, guiding the air towards an elongated, narrow passage (Majaz). This joint serves as an air filter for the air coming from the alleys and helps reduce noise generated by the surrounding streets and alleys, as illustrated in Figure (6).

Figure 6. The alleys are considered important joints of the fluid space that connects the open external urban spaces with the central courtyards in a unified spatial formation (Old Mosul)

"The traditional environment is characterized by its complete reliance on self-reacting adaptive systems for cooling in the summer and heating in the winter. The traditional dwelling, through its integration with the urban environment, represents an essential part of the ecological and climatic system. This is achieved through the urban spatial configuration to maximize the utilization of natural energy sources, such as solar radiation and air movement, along with the physical conditions that enhance the building's self-adaptation.

16- Theoretical conclusions

1. Passive conditioning systems contribute greatly to enhancing energy efficiency in buildings and therefore reduce the dependency on mechanical air-conditioning systems
2. These systems work off the natural elements, which are essentially wind and shade and achieve synergy between architectural design and the natural environment.

3. Passive solar energy concepts can be very effective at achieving thermal balance in buildings with window design and insulating materials that provide for natural heating in winter and work against heat in summer.
4. Passive cooling measures such as natural ventilation and shading enhance thermal comfort within buildings and reduce the need for artificial cooling systems.
5. Key principles of passive conditioning include: adopting the right insulating materials, proper orientation of a building to reap maximum benefits from the natural winds and elements, and automatically regulating the temperatures.
6. Passive design—the orientation of a building and the arrangement of its openings to ensure adequate flow of natural wind to the interiors—improves air quality and thermal comfort in spaces without electrical air-conditioning.
7. Passive shading is designing building facades, windows, trees, and canopies to cool passively and lessen inside heating from buildings, lessening the impact of direct sun rays.
8. The passive condition has a substantial reduction in heat impacts on dense urban centers through building and public space designs that tap into natural winds and shade. Thus, the integrated urban form with passive envelopes underscores the essential message in urban design, which is maximizing on natural factors in attaining a thermally comfortable condition that includes planning of buildings and streets with regards to wind flow directions and green spaces.
9. This signifies the importance of this approach within the urban set-up, as open areas and streets are designed to ensure natural airflow and the provision of proper shading to increase thermal comfort.
10. Streamlined spaces encourage enhanced natural ventilation in buildings by designing interiors which allow wind flow, and limit heat accumulation to be more efficient for passive conditioning."

17- Practical Aspect / Case Study: Al-Ayadi Residential Complex

1. Project Description

The complex consists of 37 buildings and includes several facilities such as: [32]

a. Schools
b. A commercial mall
c. A health center
d. A recreational club

Area m2	120.000
Number ofunits/apartment	1300
Apartment Area/m2	163/195/350/400
Number of buildingsin the complex/building	37
surface area of onebuilding/m2	717/858/1540/1760
Buildings area only/m2	45.094

2. The finishing materials of buildings are as follows:

a. Walls made of brick and stone
b. Roofs made of cement panels
c. Streets paved with asphalt
d. Green areas planted with grass

3. Geographic Location

The complex is located in the western part of Baghdad, on the Karkh side, in the Dawoodi area, Al-Qudhaat District (Judges' District), near the Baskulata Factory. The city of Baghdad is situated at a latitude of 33.34 and a longitude of 44.40, and it is 41 meters above sea level, Figure (7)

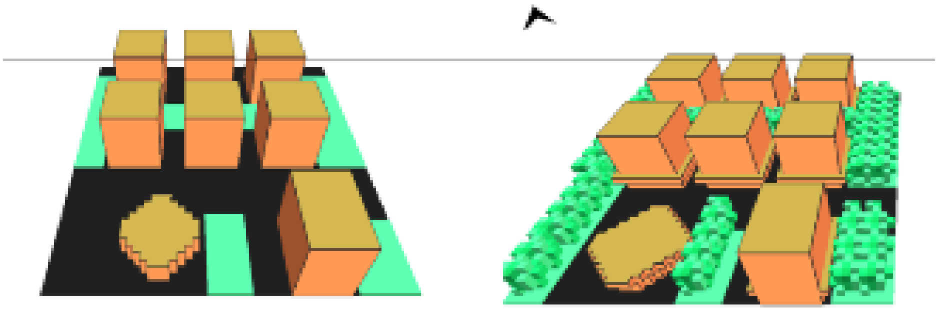
Figure 7. Several views of Al-Ayadi Residential Complex.

3- ENVI-met Models

ENVI-MET is a program that may be used for outdoor microclimate simulation in open areas, as well as wind turbulence, vegetation impact on the microclimate, pollutant dispersion, and bioclimatology input. The simulation model created by ENVI-met is according to a list of factors (e.g. clouds, structures, and soil data). A daily and hourly time range is defined by the default basic settings, including the simulation's total duration, relative humidity, wind direction and speed, and external temperature, throughout the starting and end of the simulation. Many studies have shown the trustworthiness of ENVI-met findings for modeling outdoor thermal spaces. Opened or closed shape may form light or heavy expression [33]. These examinations revealed that the data collected at local meteorological sites appeared to match the predicted outcomes with accurate and reliable validation.

4- Data for the Proposed Models

The IMOS provided the data used to simulate the suggested model. The maximum and minimum temperatures of 51.80ºC at 4 pm and 24.8ºC at 6 am were adopted to simulate the suggested models. This temperature depicted the hottest day in Baghdad registered on 28 July 2020, according to IMOS. Hence, the main conditions of the climatology environments were 315º and 3.90 m/s for wind direction and wind speed, respectively. The minimum and maximum relative humidity was 24% (at 4 pm) and 36% (at 6 am). The simulation was Held for 24 hours. A pre-processing step of the district in AutoCAD was performed before commencing the work in ENVI-met. This software was able to reconstruct the entire district using a bitmap image as a base from the AutoCAD data. The model area was calculated using a grid size with dimensions x, y, and z of 50, 50, and 40, respectively. This grid size is denoted in a grid cell of dx, dy, and dz by 2, 2, and 2 m, respectively. The model has been twisted 15º based on building adjustments and typical streets for a dry environment, Figure (8).



(A) (B)

Figure 8. (A) As-built Model and (B) The Proposed

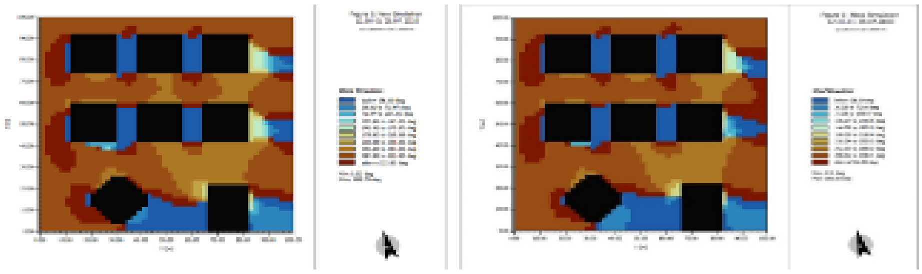
5- Analysis of As-built Model and Proposed Model:

A portion of the project was selected, consisting of seven residential buildings, each with 9 floors and a height of 30 meters per building. The streets between the buildings are 10 meters wide. The adjacent building is a recreational facility with a height of 5 meters, which has been represented in the simulation model. For the proposed model, additional structural elements were added, including a series of louvers and canopies around each building, along with increased green spaces and the addition of lush shade trees, specifically the Sophora tree, Figure (9).

Figure 9. (A) As-built Model.

Digital modeling was performed for both models, where the impact of the proposed treatments on wind movement within the selected area. The results were as follows:

a. Wind speed



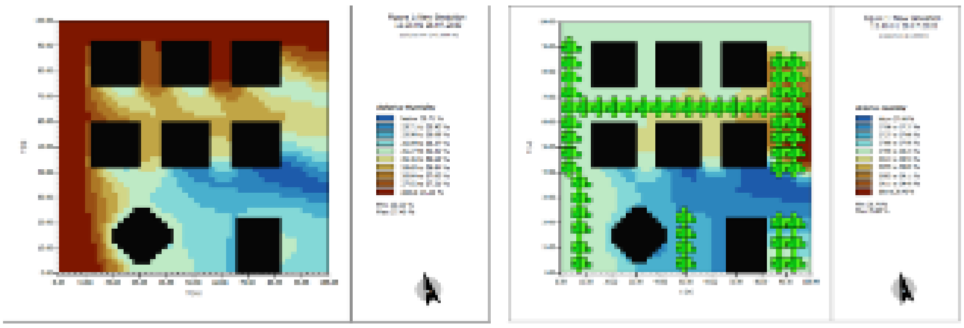
(A) (B)

Figure 10. Wind speed for (A) As-built Model and (B) The Proposed Model

Model Name	Highest Wind Speed (m/s)	Lowest Wind Speed (m/s)	Highest Movement Angle (deg)	Lowest Movement Angle (deg)
As-built Model	6.81	0.09	359.78	0.02
Proposed Model	6.66	0.03	360.00	0.10

Table 1. shows the reality model and proposed model differ in wind speed and direction. From reviewing the as-built model and the proposed model, it can be observed that the addition of shade trees has contributed to reducing wind speed and altering its direction, effectively dispersing and minimizing its hot impact. This is particularly significant during hot summer days when these winds are hot and uncomfortable, reducing thermal comfort. This change has influenced other factors that improve thermal comfort, Figure (10).

b. Relative Humidity



(A) (B)

Figure 11. Relative humidity for (A) As-built Model and (B) The Proposed Model.

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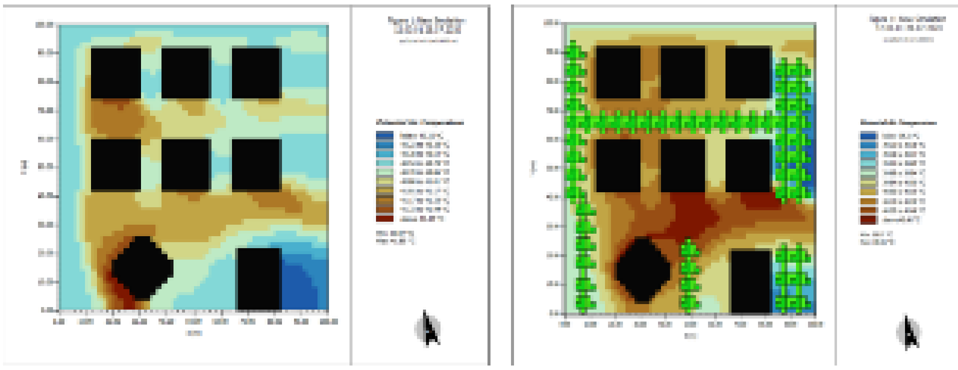
The addition of trees, which act as wind-louvers for hot winds, along with the water vapor produced through the transpiration process in the leaves, has helped to increase the relative humidity in the area. This is evident from the review of the simulation results for both models. The increased relative humidity helps to cool the hot atmosphere, thereby enhancing thermal comfort, Figure (11).

c. Air Temperature

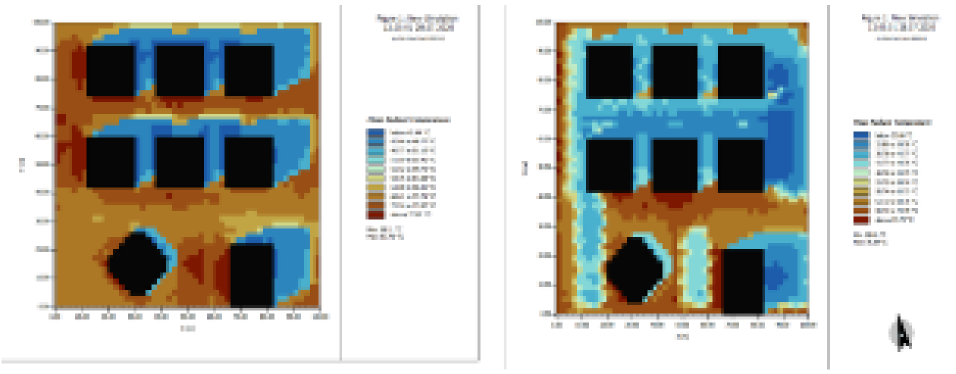


(A) **(B)**

Figure 12. Air temperature for (A) As-built Model and (B) The Proposed Model.

The proposed treatments, including wind-louvers, canopies, and trees, have helped to reduce the temperature by approximately two degrees by decreasing the coefficient of hot wind movement. This is evident in the attached diagrams, which contribute to an increased sense of thermal comfort, Figure (12).

d. Mean radiant temperature



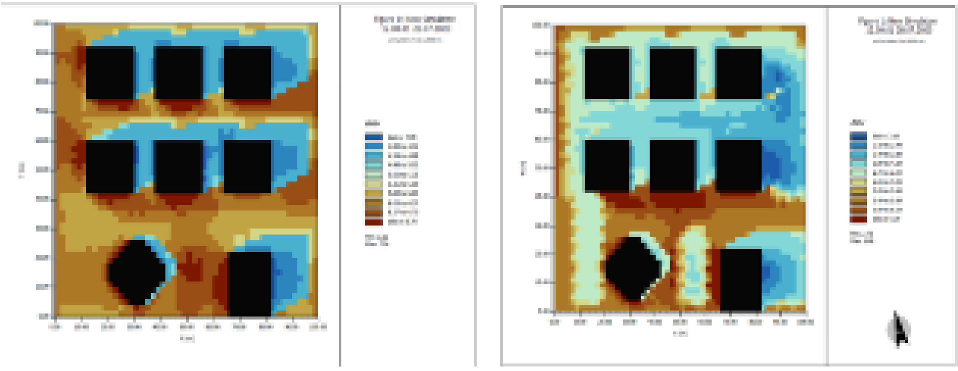
(A) **(B)**

Figure 13. Mean radiant temperature for (A) As-built Model and (B) The Proposed Model.

(A) (B)
Figure 12. Air temperature for (A) As-built Model

The reduction in radiative heat from surfaces due to the decreased speed and dispersion of hot winds helps lower the temperature of surfaces such as buildings and streets. This enhances one's perception of thermal comfort., Figure (13).

e. PMV



(A) **(B)**

Figure 13. PMV for (A) As-built Model and (B) The Proposed Model.

Each of the aforementioned factors has contributed to an increased sense of thermal comfort. Therefore, the proposed treatments have been highly successful in improving thermal comfort, Figure (14), as shown in Table (2).

Table 2. shows the results of the proposed treatments that have been highly successful in improving thermal comfort

Model Name	Highest Relative Humidity (%)	Lowest Relative Humidity (%)	Highest Temperature (°C)	Lowest Temperature (°C)	Highest Radiative Heat (°C)	Lowest Radiative Heat (°C)	Highest Thermal Comfort	Lowest Thermal Comfort
As-built Model	27.40	25.52	41.65	40.07	81.40	38.11	7.04	3.66
Proposed Model	29.69	26.79	40.61	39.07	78.69	28.81	6.68	2.70

6- Conclusions:

1. Wind movement has an impact on improving thermal comfort in urban design and forms an important aspect of city sustainability, providing a comfortable and healthy urban environment. The comparison between the proposed models and the as-built models revealed the following:
2. Wind movement plays an effective role in cooling the urban environment. When wind flows through buildings and urban structures, it improves heat exchange and increases ventilation, reducing temperatures and providing a more moderate environment.
3. Wind movement helps disperse the heat generated by urban activities and distortions in the urban structure. This reduces the impact of urban heat islands and contributes to improving thermal comfort in cities.

4. Focusing urban design attention on understanding and interacting with wind movement is an important part of making cities more sustainable and comfortable. This can be achieved through the integration of wind movement analysis in the stages of urban planning and design, ensuring a comfortable and healthy environment for residents.
5. By using wind movement effectively, the need for air conditioning and heating systems can be reduced. This contributes to energy savings and reduces carbon emissions, making cities more environmentally sustainable.
6. Dense urban infrastructure and building materials create heat islands, but wind movement can disperse this heat. This means that cities designed with wind movement in mind can reduce the effects of heat islands and enhance thermal comfort.
7. The impact of wind movement can affect pedestrian comfort in streets and pathways. Designing streets based on wind directions can enhance the pedestrian experience and create a more comfortable environment.
8. Wind movement has a pivotal role in increasing thermal comfort. The addition of windbreaks and trees that acted as wind barriers in the proposed model helped reduce wind speed, disperse it, and change its direction. This contributed to the following (see Table No. ( )):
9. Enhanced benefit from the higher relative humidity resulting from tree planting.
10. Reduced temperature levels.
11. Lowered radiative heat.
12. Increased thermal comfort as a result of the above, where the closer the thermal comfort coefficient value is to zero, the greater the sense of thermal comfort (source).

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