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# Environmental Assessment of climatic performance of coastal cities as a mechanism to achieve sustainable development: Hurghada city

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## Abstract:
Egypt faces many environmental problems. The increase in the urban population has led to an increase in the number of housing units, which changes the urban climate, or what is known as the phenomenon of the thermal urban thermal island, which is one of the biggest urban environmental problems facing the world in recent times and what followed from the steady consumption of energy, pollution and shortage resources and lack of quality of life. Hence the role of environmental sustainability and what it offers as solutions to some of these problems. Since the wind element is one of the important elements in improving the efficiency and quality of the built environment, reducing energy and thermal comfort. The main objective of the research is to focus on the importance of Computational Fluid Dynamics (CFD) simulation programs in improving the efficiency of urban settlement performance by studying natural ventilation for human health and thermal comfort, especially in the coastal communities that suffer from thermal comfort problems as an aid to planners And architects in urban planning and design to reach planning and design decisions and strategies in line with environmental sustainability standards**.** To achieve the main objective of the research, the importance of simulation programs was addressed to reach procedures and recommendations prepared to achieve sustainability and thermal comfort, the CFD model and related software treatments were applied and integrated as a small-scale wind assessment system through a number of stages, including program inputs from climatic elements and urban formation to be evaluated With the aim of guiding decision makers when designing and planning any urban assembly in order to achieve sustainable urban development.

## Keywords:
***Wind simulation programs, environmental assessment, thermal comfort, environmental sustainability assessment, sustainable environmental planning, climate analysis.***

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## Introduction
The global interest in environmental and energy issues has been reflected in the designs of global housing complexes, which conserve energy and take into account the use of local and natural materials that are environmentally friendly, adapt to the climate, and respect the site (Khalifa, 2009) as the construction of cities, with their buildings and human activities, does not change the landscape It also affects the local climate in a way that depends on many different factors and parameters: weather conditions, urban thermophysical and engineering properties, anthropogenic humidity, and heat sources. Ground cover and canopy structure play an important role in urban climatology and are confronted by every environmental assessment, city design and planning. (F Nardecchia, F Gugliermetti, F Bisegna, 2015)
Within the previous framework, the idea of simulating nature emerged as a tool and strategy to achieve urban sustainability by finding solutions to design problems. This is done through environmental simulation programs and simulation of their models, elements, functions and ecosystems (Sciences(NIMS)., 2020).
dynamics (CFD) fluid Computational Mechanics is part of one of the simulation techniques and one of the environmental assessment tools for communities that are used by planners and architects to predict climatic conditions at the level of resorts and buildings to achieve the so-called thermal comfort of coastal cities (LÖHNER, R. 2001).
Where the coastal cities, especially the Red Sea cities, receive a small amount of rain in general, and the climate of the region encourages the practice of outdoor activity on the beaches during the autumn, winter and spring seasons, except for the days when storms and winds blow, and the temperatures in the sea area during those seasons range between 8 And 28 degrees Celsius, however, the temperatures rise in the summer to much higher, as it can reach 40 degrees Celsius

with a clear rise in relative humidity, and the north and northwest winds prevail in those areas, the most famous of which is the Egyptian wind that blows strongly during the winter months. It is usually accompanied by fog, dust and dust, and during the months from June to August strong northwest winds blow from the north.

It is one of the dry regions and coasts, and it is one of the regions that are not thermally comfortable (Zahni, 2011), (worldatlas, 2019).

Which needs directives and decisions to improve the thermal comfort of the environment surrounding the human society, which in turn achieves sustainable development in these gatherings.

There are many factors and criteria that affect the planning and design of the assembly to reach sustainable development and thermal comfort. We find that wind is one of the important factors in sustainable environmental planning as it greatly affects thermal comfort. Wind is defined as the movement or transmission of air masses in the horizontal direction (atmospheric pressure). John Rechma, 1922), the wind moves an accelerating movement from areas of high pressure to areas of low pressure

Air movement is also very important for human thermal comfort, so the wind speed should not be less than 2 m/s in areas with a hot and humid climate, while in areas with a hot dry climate, it is not less than 1 m/s. The human body and the surrounding climate, so the use of air velocity as a basic criterion for natural ventilation, and there is no doubt that the air velocity is affected by the planning and internal distribution of the space (ASHRAE, A. 2004.), and also uses wind energy density as a criterion to determine the best place to obtain wind energy, which is an expression Calculations for the highest wind energy at a specific location depending on the velocity of wind blowing at a certain height above the surface for a specific period of time (Najib, 2019). All of these factors and criteria have a basic direct and indirect relationship with the wind element, and they can be dealt with through wind simulation programs to create the best planning and design practices for urban communities and achieve their sustainability.

## Methodology

The study was conducted by applying the inductive approach is the study of wind simulation programs as a tool for evaluating the environmental and climatic performance of the communities and determining their planning and design level. Apply analytical studies to a selected case

## Research problem

The research problem lies in the incompatibility of planning and designing communities in Egyptian coastal cities with climatic changes and the attendant heat emissions that affect the thermal comfort in these gatherings. Therefore, it is important to predict through wind simulation programs to guide planners' decisions

## Research objective

The research aims to apply and use one of the wind simulation programs to assess the environmental and climatic performance of the assembly with the aim of achieving sustainable development and design based on reliance on simulation as an evaluation mechanism and then guiding planners and decision makers and an attempt to achieve environmental balance in urban cities.

To achieve the objectives of the study, the research followed the following structure:

- Environmental wind simulation programs to achieve sustainable urban design and planning
- Determine the field study
- Programmatic simulation using ANSYS
- Findings and recommendations

### 1. Environmental wind simulation programs to achieve sustainable urban planning design

With the increased interest in climatic design and treatment of buildings and communities and the emergence of modern trends in climate design, the stage of climatic calculations entered a complex stage, which led to increased interest in the computer and activating its role in design and planning from the building to the urban assembly (Al-Esawy, 2007). Or some operations by building a model similar to it using computer programs, and it is usually used for the purpose of study (Search, 2021)

The computer programs for wind simulation for the environmental design of the building and the city (Al-Esawy, 2007) have varied and varied. OPAQUE and SOLAR 5-7 program for designing the elements of the building's exterior envelope, Vasari for energy modeling and conceptual analysis tools, to understand the building and analyze it accurately.

CLIMATE CONSULT, an easy-to-use program to analyze climatic information for any city according to the recorded basic climatic

information in order to obtain the main guidelines for climate design, Envi-met for analyzing and evaluating urban planning and design (Al-Esawy, 2007) as well as the Autodesk Simulation CFD program (Tanvir Sowgath, Mominur Rahman , Sabbir Ahmed Nomany, Nazmus Sakib, Junayed, 2015), Ansys as one of the most important programs interested in simulating wind and its relationship to urban formation in the assembly and other programs as shown in Table (2)

As a result of the large number of software, its diversity and variety of functions, and the difficulty of choosing among them, the best planning and engineering practices by users favor a limited group of programs that have proven a high degree of efficiency in results (Al-Rahman, 2017) based on criteria identified such as ease of use, speed, accuracy Full time results, documentation and ability to expand and solve larger problems (Rainald, 2008)

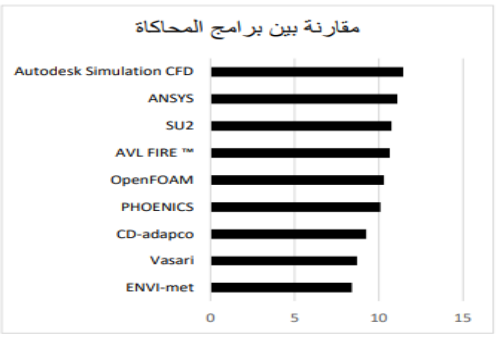
Table (2) Comparison of wind simulation software

| م | اسم البرنامج أو البرمجيات | نوع البرنامج * | (GUI) Ease of use | Documentation | Geometric flexibility | Turnaround time | Accuracy | Speed | Expandability to new areas | Benchmarking |
|---|---|---|---|---|---|---|---|---|---|---|
| | وزن التقييم | --- | ٢ | ٢ | ٢ | ١ | ١ | ١ | ١ | ٢ |
| ١ | ANSYS | C | ٠,٧ | ١,٠ | ١,٠ | ٠,٨ | ٠,٩٥ | ٠,٩٥ | ١,٠ | ١,٠ |
| ٢ | Autodesk Simulation CFD | C, EL | ١,٠ | ٠,٩ | ١,٠ | ١,٠ | ٠,٩٥ | ٠,٩ | ٠,٨ | ١,٠ |
| ٣ | AVL FIRE™ | C | ٠,٧ | ١,٠ | ١,٠ | ٠,٨ | ٠,٩٥ | ٠,٩ | ٠,٦ | ١,٠ |
| ٤ | CD-adapco | C | ٠,٧ | ٠,٧ | ١,٠ | ٠,٨ | ٠,٩٥ | ٠ | ٠,٩ | ٠,٩ |
| ٥ | OpenFOAM | OS | ٠,٥ | ٠,٩ | ١,٠ | ٠,٨ | ٠,٩ | ١,٠ | ٠,٨ | ١,٠ |
| ٦ | PHOENICS | C | ٠,٦ | ٠,٩ | ١,٠ | ٠,٧ | ٠,٩ | ٠,٨ | ٠,٩ | ٠,٩ |
| ٧ | SU² | OS | ٠,٦٥ | ١,٠ | ١,٠ | ٠,٨ | ٠,٩٥ | ٠,٩ | ٠,٨ | ١,٠ |
| ٨ | ENVI-met | C, EL | ٠,٧ | ٠,٥ | ٠,٨ | ٠,٧ | ٠,٧ | ٠,٨ | ٠,٦ | ٠,٨ |
| ٩ | Vasari | C, EL | ٠,٨ | ٠,٥ | ٠,٩ | ٠,٨ | ٠,٨ | ٠,٩ | ٠,٦ | ٠,٦ |

* **OS** → Open Source | **C**→ Commercial | **EL** → Educational Licence

Source: Mahmoud Mohamed Mohamed Ali Abdel Rahman, The Role of Wind Simulation Techniques in the Environmental Sustainability of Architecture and Urbanism: A Case Study on Medium Cities, 2017

Based on the previous criteria, these programs were evaluated and compared digitally, as shown in Figure (1) of the previous table. It is clear that - and according to the standards and practices, we find that CFD Simulation Autodesk and ANSYS programs are considered among the most powerful wind simulation programs currently on the scene, despite They do not specialize in architectural and urban design compared to programs such as met-ENVI, but these programs are characterized by accuracy, high speed, and availability of educational and information sources. In this research, the application of the Ansys wind simulation program will be relied on as one of the most important programs interested in shaping (Najib, 2019).




| اسم البرنامج | التقييم |
|---|---|
| Autodesk Simulation CFD | 11.45 |
| ANSYS | 11.1 |
| SU2 | 10.75 |
| AVL FIRE ™ | 10.65 |
| OpenFOAM | 10.3 |
| PHOENICS | 10.1 |
| CD-adapco | 9.25 |
| Vasari | 8.7 |
| ENVI-met | 8.4 |

Figure (1) Comparison of simulation programs according to the above-mentioned criteria in Table (2)
Source: Mahmoud Mohamed Mohamed Ali Abdel Rahman, The Role of Wind Simulation Techniques in the Environmental Sustainability of Architecture and Urbanism: A Case Study on Medium Cities, 2017

## 2. Research Work

This research is based on the case study, which is one of the important means in achieving and testing the results, and this method is suitable for use in the case of the presence of different variables and factors related to each other.

- Determining the study area, the problem, and the simulation programmatically for the site and the proposed formation, through basic stages (determining the inputs (climatic data) and the factors affecting the climatic data - the introduction of the urban plan to the wind simulation programs until reaching the exact real result with the required values - the third stage "outputs" are Determining the urban requirements and recommendations for decision makers)

**2-1 The study area and the problem of the site**

The city of Hurghada is the administrative capital of the Red Sea Governorate. The city is located in the central eastern part of the governorate in an intermediate location between the city of Suez and the city of Al-Qusair. The urban mass of the city is concentrated in the form of a strip parallel to the west bank of the Red Sea coast, about 1 km from the interior in most of its parts. The city is considered a tourist city with A special character, as the city has become one of the most popular tourist places in Egypt and the Middle East for tourists (Al-Omrani, 2017)

The entire governorate is considered one of the dry desert areas. This clearly appears due to its hot, continental climate. The northern part of the Gulf of Suez is more vulnerable to weather fluctuations, especially in the winter season, in the case of the weather in the Mediterranean.

The main problem in the city of Hurghada and its extension is the decrease in thermal comfort inside the city, due to the high temperature in the city, the average temperature is 38 m, with a high relative humidity throughout the year 40% in the morning and rises 5-10% in the afternoon, in addition to the highest wind speed In the city: 16 km / h Average wind speed in the city: 13 km / h The lowest wind speed in the city: 12 km / h The prevailing direction of the wind: North and Northwest, which in turn led to a decrease in the percentage of tourists to 7%, equivalent to 10% from inside the city in the sector Tourism, with electric energy consumption rising at a rate of 50% of the total energy consumption (weather, 2021).

the necessity of simulation to evaluate climate performance to improve thermal comfort to improve the urban environment and achieve environmental sustainability, using wind simulation models to guide the urban formation of the extension of Hurghada city to improve wind entry through the urban fabric, and achieve an urban environment with thermal comfort.

**2-2 Simulation programmatically**

The Ansys program will be used as one of the wind simulator programs in the extension of the city of Hurghada to guide decision makers to a set of planning and design decisions when preparing urban plans in the extension areas in coastal areas that suffer from thermal insufficiency. The application will be through several steps:

- Analysis and evaluation of the climatic conditions in the case of the study
- Assessment of the current status of the urban formation of the extension area
- Determine planning and design decisions to guide the formation of the future plan of the extension area

**2-2-1 Analysis of climatic data for the case of the study**

Simulation programs are one of the important means of obtaining the desired results to improve the thermal comfort of the human being within the built environment. Climate data is one of the most important inputs of these programs to reach accurate results that guide planning and design decisions.

There are wind data in Egypt in several areas for the meteorological stations. These areas are distributed over the different climatic regions in Egypt at the rate of one or two stations in each region, in addition to the weather stations located in the airports. One of the most important problems that the researcher faced while conducting the research, The absence of a meteorological station in the area of the study case, so the researcher used the nearest meteorological stations, including some mathematical models that calculate the data of any region. Through many studies, this method has been documented, achieved, and proven highly accurate and efficient in deducing climate values in any region.

The entire governorate is considered one of the dry desert areas, and this clearly appears on its hot continental climate. The northern part of the Gulf of Suez is more vulnerable to weather fluctuations, especially in the winter season, in the case of the Mediterranean

- **Climate :**

The average daily temperature in the city of Hurghada is below 20°C in January, while its maximum in August is 30°C. The average temperature range of the city, which is the difference between the maximum and minimum extremes, is 14°C, as it decreases in summer to 13°C and averages 16°C in winter, and this indicates a hot climate throughout the year. illustrated as (4)

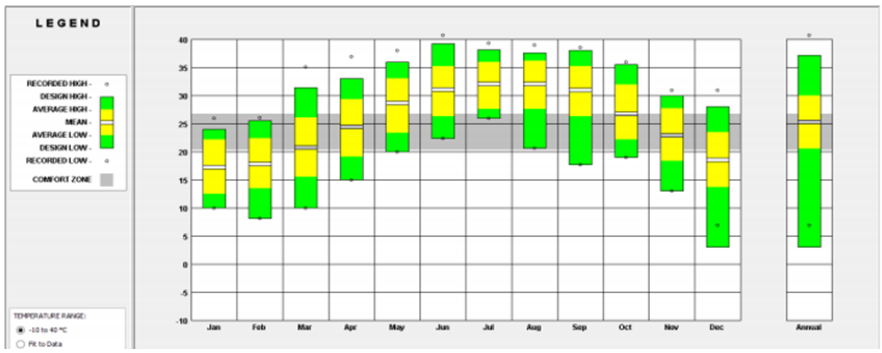



Figure :The general climate of Hurghada and its extent
Source: https://www.meteoblue.com/en/country

**• Relative humidity**

The monthly average relative humidity reaches a maximum in September and January, where it reaches 60%, and decreases to its lowest in June, where it reaches 47%.

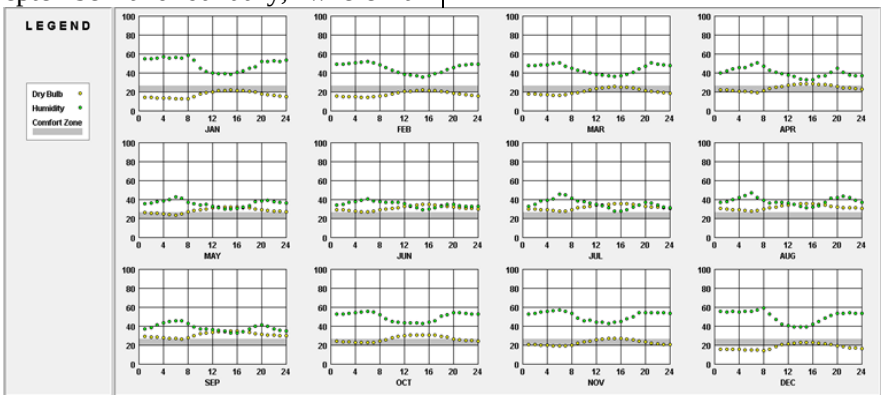



Figure :Relative humidity throughout the year for the city of Hurghada and its extent
Source: https://www.meteoblue.com/en/country

- **Clouds and solar brightness**

The amount of clouds in the sky affects the extent of solar brightness, and the data indicated that the average sky coverage with clouds is 11% throughout the year, with a brightness of 70%, and the duration of brightness in summer and winter reflects the high thermal energy that must be taken into account in the design of buildings or in any other energy-powered purposes solar

- **Atmospheric pressure and wind:**

In the winter months, especially in January, it reaches a maximum of 6.16.1 billion, while its lowest in July is 04.1 millibars. The winds show that their prevailing direction is northwest as shown in Figure (7), followed by the north, except for the months of January and September. The wind blows from the west and is less and almost non-existent. In the rest of the directions, the percentage of stillness increases in summer, reaching 2%, and decreasing to 1% in winter. Winds whose speed is limited between 11-16 knots, about 20 km/h, have the maximum frequency throughout the months of the year, reaching 305 of the total winds, which is considered a Buffus scale. From the moderate breeze that forms the upper limit before the wind turns into an uncomfortable element that must be resisted and protected from. The average rate of wind frequency that falls below this limit is 75%, followed by strong winds whose speed is limited between 17-21 knots, or 38 km / h, does not exceed It accounts for 15% of the total winds with an increase in their speed, mostly in the summer months - the conclusion is that the winds are generally moderate, except for short periods in the summer months, their speed increases, but the absence of high-speed winds in winter helps reduce the feeling of cold ز

- **Climate assessment**

To assess the climate of the region in relation to the comfortable conditions of the person, the Evans Scale was used in this study in order to give a clear picture of the climate of the region and its location in relation to the thermal comfort of the person.

During the day, the weather is hot in May and October, and it can be treated by design without resorting to artificial mechanical methods due to the high temperatures above the thermal comfort limit, as for the cold in the months of November to April, it can be treated by wearing heavier clothes and reducing air movement within the vacuum.

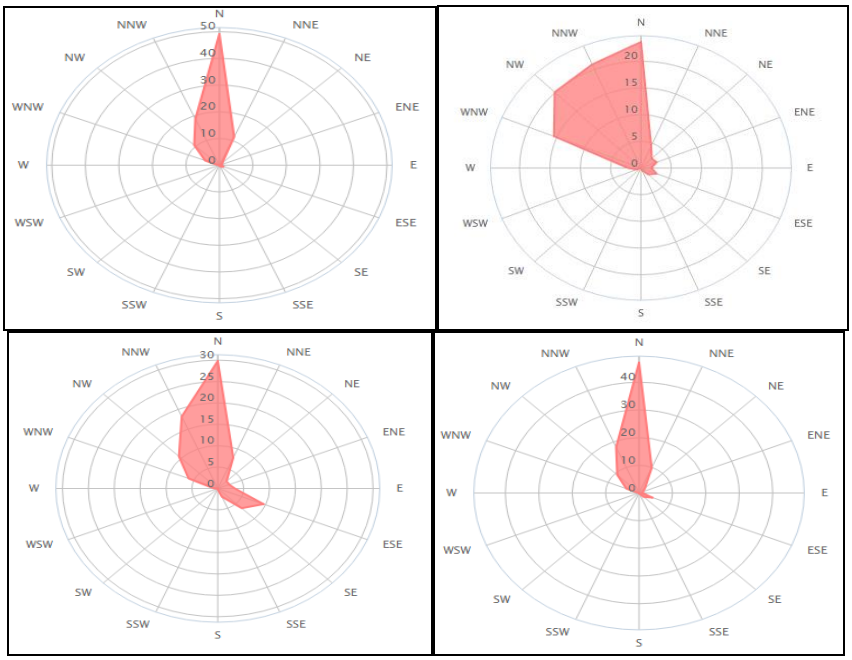



Figure :Atmospheric pressure and winds of the city of Hurghada and its extent
https://www.meteoblue.com/ar/country

At night: it is possible to treat the natural coldness from and exploit the heat energy during the day in heating the nights. It should also be noted that the months that need cooling are 4 months, and the cold period that needs heating is 3 months, which is a percentage that needs to focus on cooling during the day regardless of the cooling at night , as Figure (8) shows the ranges of thermal comfort for the lowest months of the year from thermal comfort in October

| المعاصر المناخيه | يناير | فبراير | مارس | ابريل | مايو | يونيو | يوليو | اغسطس | سبتمبر | اكتوبر | نوفمبر | ديسمبر |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| الاشعاع الشمسي المباشر(ميجاوات/ م2) | 587 | 608 | 592 | 611 | 594 | 645 | 625 | 616 | 615 | 579 | 551 | 538 |
| الحراره العظمى (درجه مئويه ) | 30 | 32 | 35 | 40 | 43 | 46 | 44 | 42 | 43 | 43 | 35 | 32 |
| الحراره الصغرى (درجه مئويه ) | 11 | 11 | 14 | 18 | 22 | 25 | 26 | 26 | 24 | 20 | 14 | 12 |
| متوسط الحراره (درجه مئويه) | 21 | 23 | 25 | 29 | 32 | 35 | 36 | 36 | 34 | 31 | 26 | 22 |
| الرطوبه (%) | 49 | 44 | 44 | 40 | 35 | 35 | 35 | 38 | 38 | 50 | 50 | 50 |
| سرعه الرياح (كم/ س) | 12 | 12 | 14 | 13 | 14 | 16 | 14 | 16 | 16 | 13 | 12 | 12 |
| اتجاه الرياح (درجه) | 300 | 270 | 280 | 300 | 350 | 340 | 300 | 340 | 310 | 340 | 300 | 290 |
| PMV | 0.89 | 1.14 | 1.43 | 1.47 | 2.57 | 3.5 | 2.92 | 2.27 | 2.75 | 3.23 | 1.68 | 1.16 |

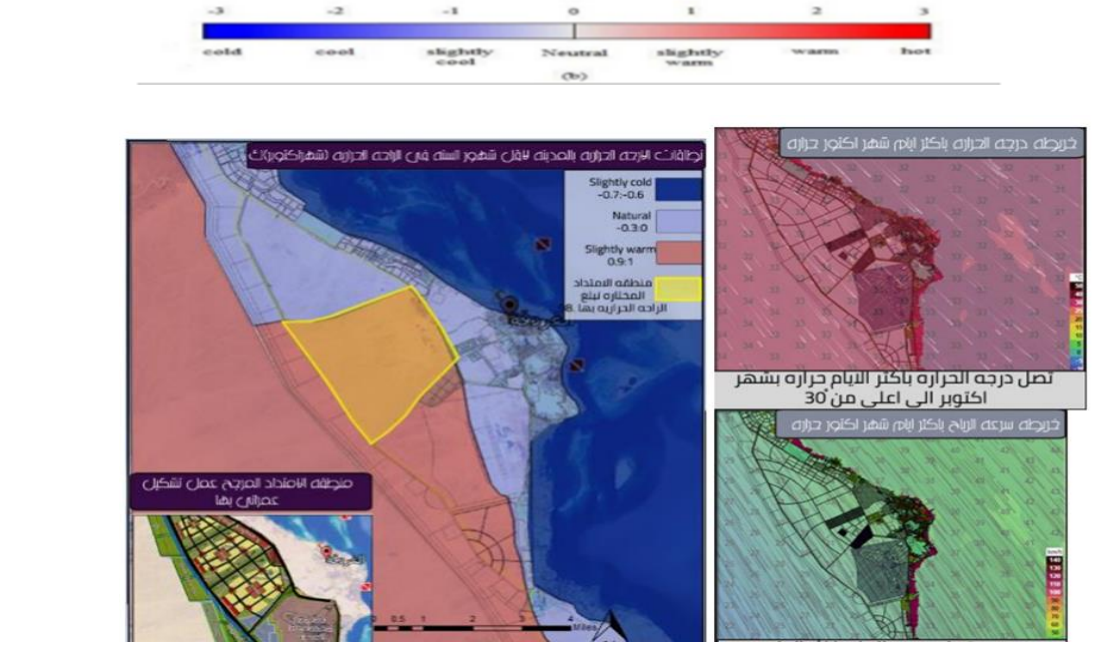



Figure :Thermal comfort ranges for the lowest months of the year from the thermal comfort month of October

- **Factors affecting the climate:**

The factors affecting the first priority that affect the study of the climate will be addressed, including topography, soil, and proximity or distance from the water body, as shown

## 3. Discussion

### 2-2 Evaluation of the current status of the urban formation of the extension area

A model of urban formation is entered for the proposed plan for the extension area, including the distribution of blocks, afforestation, roads and urban fabric in order to analyze and evaluate the proposed status of the formation based on the urban formation and the simulation program. .

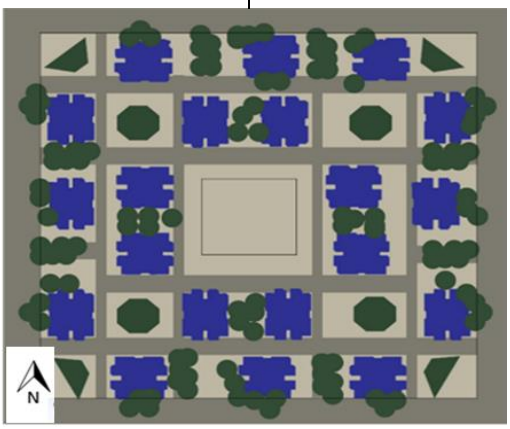



Figure :Basic urban formation data for a model of the extension of Hurghada city
Source: the researcher

Through ansys simulation of the proposed model for the extension of the city of Hurghada in the previous form, figure emerged, and through it some basic results appeared that represent strengths or weaknesses of the proposed formation that appear as follows:

- The strengths represented in the fact that the wind speed in the eastern and western sides reaches 8 m/s, the direction of the sun's shadow in the morning and evening led to a decrease in the air temperature and an increase in its speed and pressure, the wind speed in the central region is 6 m/s as a result of formation, the winds are collected within the vacuum Orientation in the direction of the north winds and in the direction of the sea, the rectangular shape shows 50% of the directions to the winds.

The weaknesses that need to be evaluated and updated with the proposed plan are represented in the wind speed on the north side 4 m/s, buildings with one height which led to a lack of air access behind the building, external street widths which led to a lack of shading on the buildings where the width of the street does not match the height of the building, the spread The shrubs between the residential blocks stand as a crossbar for the passage of the wind, cement streets absorb 18% of the sun's rays, there is no water source that works to moisten the air, despite the orientation towards the sea, but the vision is difficult due to the formation of compact blocks.

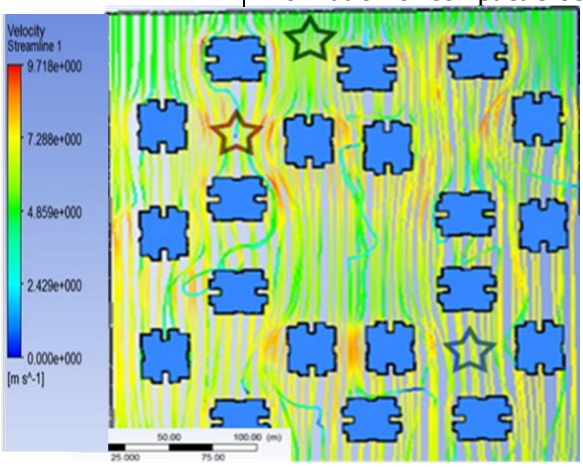


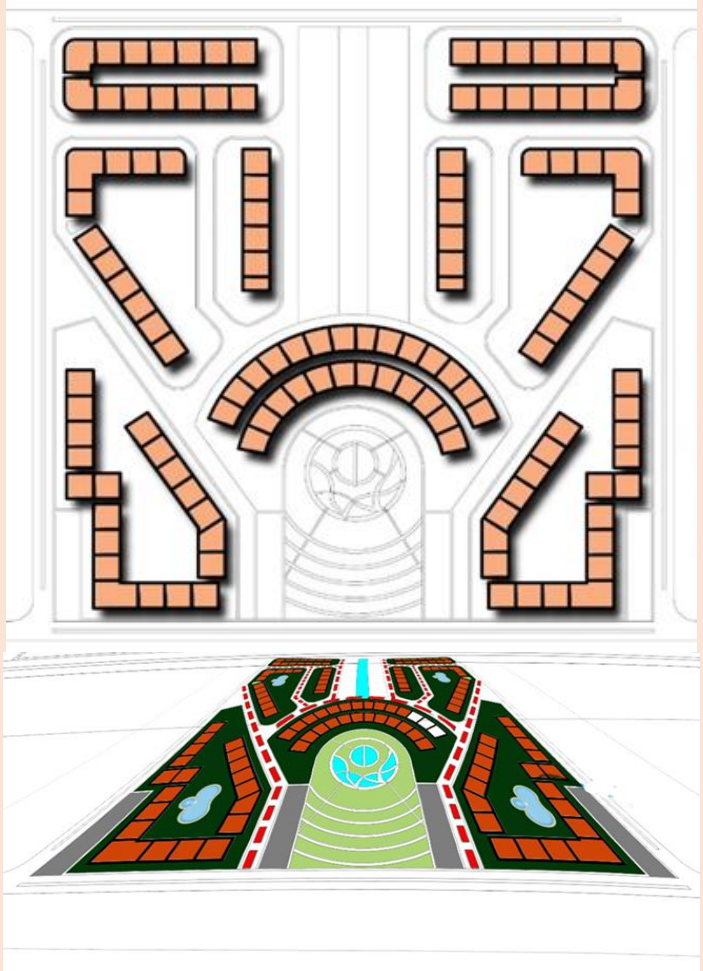
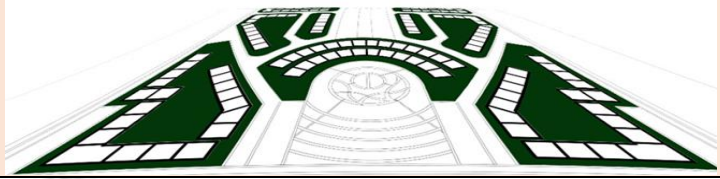
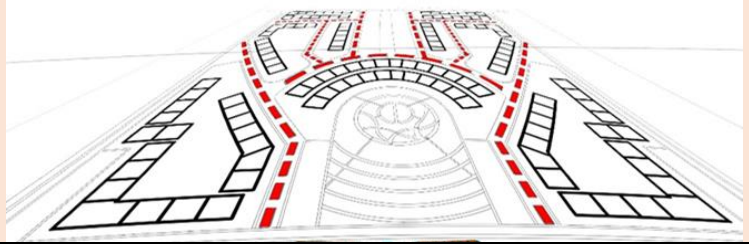

Figure :Environmental simulation of the urban formation model for the proposed extension of Hurghada
Source: researcher acting on the simulation program ansys

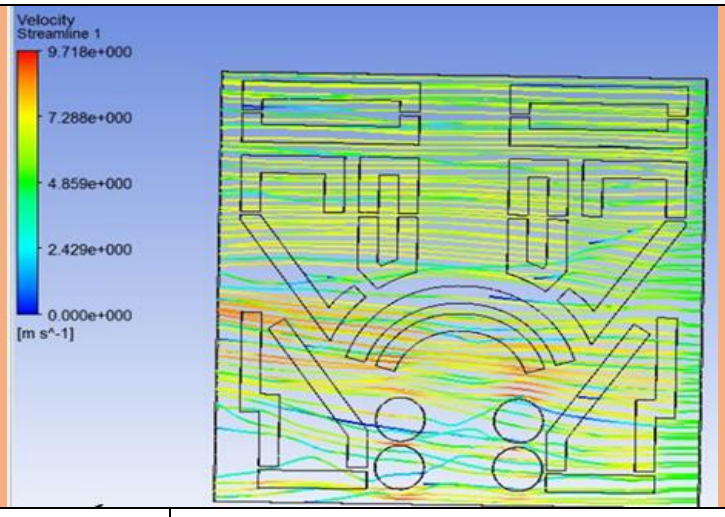
**2-2-3 Determining the planning and design decisions to guide the formation of the future plan of the extension area**

Outputs are the identification of a set of planning decisions based on identifying the strengths and weaknesses from the previous analysis to guide decision makers and planners when preparing urban plans. Those decisions were divided into a group of elements related to orientation, weaving, spaces, height, formation, and afforestation. The following is a presentation of a group of planning decisions

Solutions will be proposed for the urban formation of the extension area, including the urban fabric, roads, green areas, shading areas, and simulation of the model again to show the extent of improvement in the surrounding urban environment to achieve the best thermal comfort Table.

Elements of achieving thermal comfort in the proposed Hurghada city extension model based on ansys

| | |
|---|---|
| urban formation<br><br>Shaping provides up to 40% shade ratio.<br><br>Residential use rate 52% |  |
| green areas The percentage of green areas is 8% |  |
| roads<br><br>Road Ratio 8% |  |

| | |
|---|---|
| Programmatic simulation result<br><br>A wind speed of 9 m/s and a minimum speed of 5 m/s, meaning that the speed increases |  |

Source: researcher

## Results and Conclusion :

Assessment of environmental and climatic performance using the simulation program is considered a mechanism to guide decision makers and planners when preparing urban plans.

From studying, analyzing and evaluating the climatic situation using CFD wind simulation programs, the importance of wind simulation programs has emerged as real oriented tools as they play the role of analysis and evaluation of the city's work system to achieve environmental sustainability and then sustainable development. Urban and design, which can be taken into account when preparing urban plans along the city of Hurghada to achieve thermal comfort and then the possibility of attracting internal and external tourism and achieving economic development.

CFD wind simulation programs help decision makers and stakeholders to identify weaknesses and challenges that must be developed policies and strategies for cities in order to reach sustainability while facing and preparing for the risks that may face them, and the application of this tool in Hurghada will guide decision makers and officials in Hurghada to reach the real challenges in each sector to achieve planning environmentally sustainable in the right way.

The research sought to try to use methods to achieve the principles of environmental sustainability, based on the element of wind and natural ventilation, a quantitative study based on wind simulation programs as an effective element.

Emphasis on increasing interest in environmental studies and the impact of climate on the environment, as they are useful in achieving sustainable development and provide an opportunity to advance all aspects of the human and natural environment in light of changes and climatic conditions.

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