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ENHANCING THE PERFORMANCE OF NATURAL VENTILATION BY THE EFFECT OF SPATIAL CONFIGURATIONS IN HOT-ARID CLIMATE

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ABSTRACT

Recently, Air is considered one of the most essential elements to human life as it affects indoor air quality, thermal comfort, and energy saving. At the early design stages, architects focus more on the general mass, layout, geometry, and shape of buildings and their influence on the air flow and natural ventilation than the spatial configuration. The handling of natural ventilation neglected as a base solution to achieve good internal environment for interior architectural spaces, users' health considerations, and their economic income. Therefore, this research tries to find the relationship between spatial configuration and natural ventilation, the potential of using space syntax approach to predict the effect of spatial configuration to the air movement to help architects at early design stages. The layout of a social housing unit in El-Shourouk city chosen as a case study. The results find a linear correlation between the two indicators: connectivity value and, in both building and room level.

KEYWORDS: Natural Ventilation, Spatial Configuration, Social Housing, Space Syntax, CFD Model.

تعزيز أداء التهوية الطبيعية من خلال تأثير التكوينات الفراغية في المناطق المناخية الحارة القاحلة

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الملخص

في الآونة الأخيرة، يعتبر الهواء أحد العناصر الأساسية لحياة الإنسان لأنه يؤثر على جودة الهواء الداخلي والراحة الحرارية وتوفير الطاقة. في مراحل التصميم المبكرة، يركز المهندسون المعماريون بشكل أكبر على الكتلة العامة والتخطيط والهندسة وشكل المباني وتأثيرها على تدفق الهواء والتهوية الطبيعية أكثر من التكوين المكاني. يتم تجاهل التعامل مع التهوية الطبيعية كحل أساسي لتحقيق بيئة داخلية جيدة للمساحات المعمارية الداخلية، والاعتبارات الصحية للمستخدمين، ودخلهم الاقتصادي. لذلك، سيحاول هذا البحث إيجاد

العلاقة بين التكوينات الفراغية (spatial configurations) والتهوية الطبيعية، وإمكانية اســتخدام منهج بناء الجملة في الفضـــاء (space syntax approach) للتنبؤ بتأثير التكوين الفراغي على حركة الهواء لمسـاعدة المهندسـين المعماريين في مراحل التصـميم المبكرة. تم اختيار مخطط وحدة الإسـكان الاجتماعي بمدينة الشـروق كدراسـة حالة. أظهرت النتائج العرض أن هناك علاقة خطية بين المؤشرين: قيمة التوصيل (connectivity value) و سرعة الرياح (wind velocity)، في كل من مستوى المبنى والغرفة.

الكلمات المفتاحية: التهوية الطبيعية، التكوينات الفراغية، الإسكان الاجتماعي، بناء الجملة في الفضاء، نموذج CFD

1. INTRODUCTION

At present, the ventilation process is a crucial necessity for a healthy lifestyle and its significance is further underscored by the current worldwide outbreak of Covid-19. The process of natural ventilation is mainly depending on replacing indoor air by fresh air from outside this process happens in order to achieve thermal comfort of occupants and indoor air quality (IAQ) without more consuming of energy [1], As building sector is the largest consuming energy by 42% of the total energy consumption in the world [2], this sector responsible for 33% of carbon emissions in the world. HVAC system is considered one of the most sources that consume large amount of building energy to nearly 60% of global energy consumption in building sector, so using a passive strategy as natural ventilation considered as one of the most promising methods for decreasing the amount of building energy consumed and to provide fresh air inside the buildings to give thermal comfort [3,4,5].

No doubt, space plays a significant role in architectural design because space is the main element used by occupant. For architectural space, the core issue is the relationship between interior spaces, interior space, and outdoor space (building and environment) and outdoor space (urban environment). However, it is easy to ignore that spatial design is also significant for building performance especially for thermal performance. The spatial configuration in a particular building can influence the physical environment (thermal environment, lighting environment), and occupant's activities (movement, living style, etc.) and feeling in the space (stimulation, visual, thermal, aural comfort, etc.). Thus, being able to combine spatial analysis and building performance analysis to create a proper building form and a comfortable and energy efficient environment is in the early design stages [6].

At early design process, decisions which taken is may significantly affect the final building performance. Airflow paths affected by the arrangement of spaces, orientation of floor plan and the size and orientation of the exterior openings and this affect indoor thermal comfort. In the interiors natural ventilation might reflected more in open spatial connections. Therefore, Natural ventilation concept integrated in the body of the building and will consequently influence the architecture, in the exterior as well as in the interior. So, understanding the mutual relation between the spatial configurations and natural ventilation become a great challenge in decision making in the early design stages [7,8]. To aid architectural designers' performance-based design (PBD) at early design stage has become a vital principle. Space layout design which produced as a result of arrangement of spaces is a major step in architectural design process [9]. This process aims to finding the maximum number of design proposals that satisfy the needs of both designer and occupants [10].

In this research the mutual relationship between spatial configuration and natural ventilation detected by using space syntax approach as it is the significant tool to get connectivity value of spaces so predicting the effect of spatial configuration to the air movement after comparing results with the base case CFD simulation modelling by using Design Builder simulation tool to help architects at early design stages.

2. OBJECTIVES

The main objective of this paper is to investigate the role of the spatial configuration potential in inducing natural ventilation performance in case of an existing low-cost housing units located in Cairo, Egypt. The paper shows the design principles and concepts that shape naturally ventilated buildings in this region and find out the relationship between the spatial configuration and the natural ventilation performance.

3. RESEARCH PROBLEM

The harsh climatic conditions that face the low-cost housing units in hot arid regions make it urgent to design climatic responsive dwellings, as it proved that hot arid climates suffered from poor thermal performance and Indoor Air Quality (IAQ). And, enhancing natural ventilation performance not only enhance the indoor air quality (IAQ) for the users but also reduce energy consumption, as one of the great problems that face Egypt is the increase in energy consumption in compared to the energy supply. However, designing a building for optimal natural ventilation is still a challenge in the early design stages because architects focus more on the general mass, layout, geometry, and shape of buildings than other details as configuration of spaces and its relationship with natural forces

4. RESEARCH HYPHTESIS

The spatial configuration by using space syntax technique can improve the performance of air movement and thus natural ventilation in an existing residential space. Moreover, simulation tools can used to predict the performance of the proposed method to prove this relation.

5. RESEARCH METHODOLOGY

The research methodology embraces a mixed strategy which required to investigate various aspects of the study. It comprises literature review, data collection and analysis. As well as applying the methodology on the analyzed case studies to detect the applicability of the effect of the strategy of spatial configurations method and its effect on enhancing natural ventilation.

5.1. Phase One: Developing The framework (Theoretical phase)

A literature review about the main definitions and principles for space design and natural ventilation to provide a comprehensive analysis of the performance of natural ventilation and its relationship with spatial configurations.

5.2. Phase Two: Implementing and validating the framework (Applying phase)

Case study on a low-cost residential building prototype at El-Shorouk city:

- **Space syntax analysis using (Depthmap10):** to obtain the justified graph, connectivity value and VGA map.
- **Creating BIM model using (Design Builder):** to provide detailed building geometry and configuration with accurate position of each individual components (such as wall, column, and slab).
- **CFD Simulation using (Design builder):** software to evaluate the indoor temperature and wind velocity, as it used to measure the efficiency of natural ventilation expressed in terms of air change per hour (ACH).
- **Comparative analysis:** of space syntax analysis with the measured wind velocity and CFD simulation of for the case study to verify that spatial configurations have an influence on natural ventilation performance.

6. HOT-ARID CLIMATE

Arid climates are the regions characterized by dry dessert (includes wind and dust) areas, low relative humidity, the high-temperature difference between day and night, high radiation level, little rainfall, and vegetation coverage [11]. it covers 33% of the Earth, located 30 degrees north and south of the equator as Central Asia, North Africa, and inland Australia [12]. According to Koeppen's climate classification most regions of Egypt considered as Sahara Desert, and this region is the most extensive arid area on the earth as shown in **Figure 1** [11].

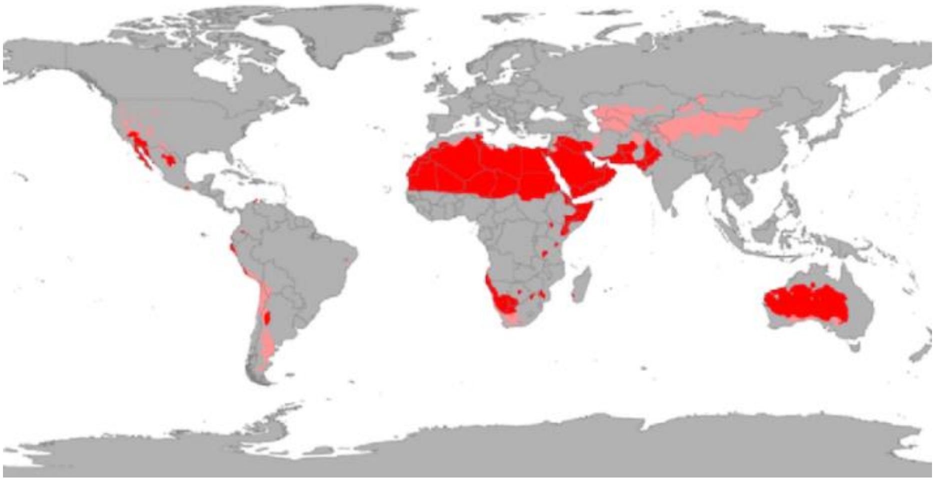


Figure 1: Hot Arid Regions through the Earth [11].

In hot-arid regions buildings are suffering from low air velocity and high solar radiation this leads to high loads of air conditioning in summer and thus increasing in energy demand[13] so the main issues of that region are how to reduce the amount of heat that affect building and the second one is providing cooling[14], Accordingly, there is a need to use natural ventilation strategies to regulate relative humidity, control internal temperature and decrease heat gain load of interior spaces inside building[15]. It is concluded that building attributes and thermal characters depend mainly on the efficiency of the natural ventilation of the spaces, difference of thermal level among different parts of the buildings regulates air flow.

7. FUNDAMENTALS OF NATURAL VENTILATION

Ventilation: is the amount of fresh air that needed for the occupants to breath and reduce odors, moisture, and pollutants. For the comfort and the health of occupants It is substantial in all types of buildings, it is also need for building integrity [16,17].

Natural ventilation: is accomplished by infiltration (the word 'infiltration' is used to describe the rando m movement of outside air through leakage paths in the envelope the building) and by opening windo ws and doors to allow air to flow into and out of a building [1]. it depends on natural forces more than mechanical equipment as fans and HVAC systems, it provides thermal comfort for occupants beside providing fresh air to the space [18].

Natural ventilation benefits are various. It considered as a low-cost passive method [19], Ventilation itself is essential to human health, comfort, and well-being [4,11]. it is contributing to achieve sustainable environment for the building. and can also reduce energy consumption. Occupants also prefer having their own control on their environment as they do not want to completely segregate from their external environment. So natural ventilation can satisfy these needs which cannot achieved from a conventional conditioning system [20].

Thermal Comfort can achieve through indoor air quality (IAQ) aspect as air is an important for general life sustenance [21], it is the resultant of the interact between the user, the building and its surroundings and it direct affect satisfaction level of human comfort [22]. so, we can widely use natural ventilation strategy to enhance occupants' health through improving Indoor Air Quality (IAQ) [1].

Also, one of the most recognized factors that affect the sense of comfort is Natural ventilation due to the passing of the air over the human skin produce cooling which is the major factor of thermal comfort. Thus, in hot-arid or hot-humid regions air velocities are important in producing desirable ventilation which is in a direct relationship with behavior, health, and comfort [23,24].

8. NATURAL DRIVERS FOR NATURAL VENTILATION

Natural ventilation created by either wind forces, buoyancy forces, or a combination of both. These two forces can exploit to ventilate a space by promoting the implementation of strategies: single-sided ventilation, cross ventilation, or stack ventilation; and this, through some architectural features such as wind towers, wind scoops, chimneys, double facades, atria, among others in **Table 1**. Finally, the determination of the natural airflow rate depends on the strategies implemented and this is the concept of natural ventilation as shown in **Figure 2** [25]

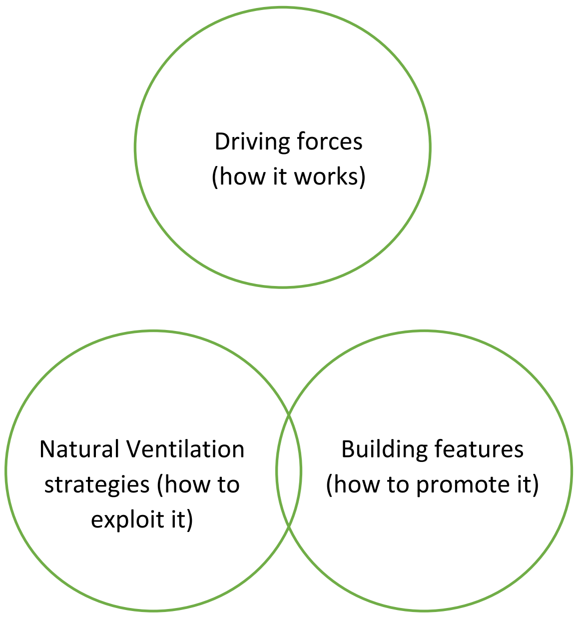
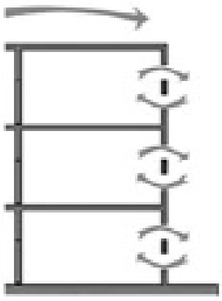
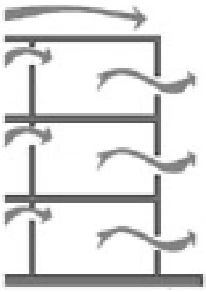
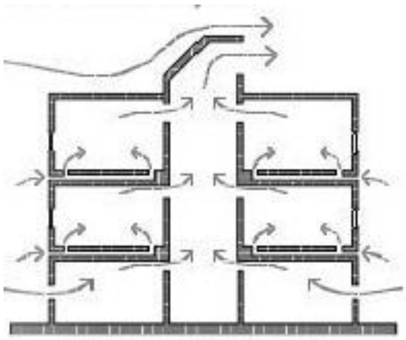
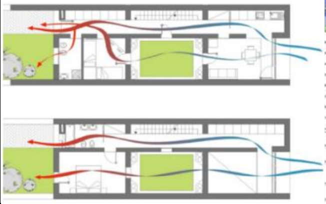
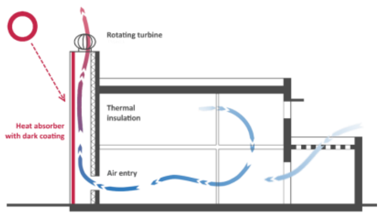
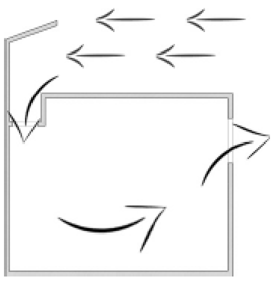
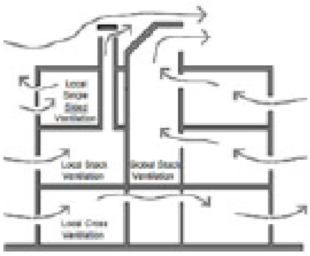


Figure 2: Natural ventilation concept researcher after [25].

Table 1: Summaries to natural drivers for natural ventilation and its applications researcher after [26].

<table>
<tr><td colspan="6">Strategies</td></tr>
<tr><td rowspan="2">Wind forces</td><td>Single sided ventilation</td><td>Cross ventilation</td><td rowspan="2">Buoyancy forces</td><td colspan="2">Stack ventilation</td></tr>
<tr><td></td><td></td><td colspan="2"></td></tr>
<tr><td rowspan="4">Applications</td><td colspan="2">Courtyard</td><td rowspan="4">Applications</td><td colspan="2">Solar chimney</td></tr>
<tr><td colspan="2"> </td><td colspan="2"></td></tr>
<tr><td colspan="2">Wind Catcher</td><td colspan="2">Wind Tower</td></tr>
<tr><td colspan="2"> </td><td colspan="2"></td></tr>
<tr><td rowspan="2">Combined</td><td colspan="5">Wind ventilation + Stack ventilation</td></tr>
<tr><td colspan="5"></td></tr>
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8.1. Spatial Driven Forces for Natural Ventilation

Firstly, there is a need to clarify the meaning of spatial configurations as it is to divide the space to configuring spatial shape vertical and horizontal surfaces are used in this formation. According to (Peponis,1997), the term of spatial configuration is used to refer to the structure of potential movement and copresence as determined by the placement of boundaries in space and by the connections and disconnections between areas that results from the presence of boundaries. So, the existing building shape is act like one matter, but the spatial configuration makes another built shape with also another source of discussion [27]. To support the effect of natural forces it is needed to create shapes and forms. It found that as the effect of spatial pressure different air can move in all directions depends on spatial pressure. However, air can move in all directions depending on spatial pressure differences [11].

The term “natural ventilation in interior architecture” also refers to systems designed to control the quality and quantity of air movement, and use it to achieve sustainability through achieving thermal comfort or internal air quality, as natural ventilation can be very effective in maintaining interior thermal comfort in an acceptable functional manner, where It is considered a technique of passive cooling, which is suitable in all climatic regions, and an ever-changing adaptive solution and responding to climate changes while emphasizing that well-designed natural ventilation systems can significantly reduce energy consumption[28] as shown in **Figure 3**.

To leads fresh air into the building and stale air out of the building natural forces is needed to drive air movement and 3-dimensional flow path. Flow path and its design considered as a matter in the issue of space connectivity by either vertical or horizontal connection or a combination of them. Large pressure gradient can be created by connecting the spaces of the building through the path. Thus, it is needed to start with investigating external forces to designing for natural ventilation. The intensity and the direction of these natural driven forces and the spatial composition of the flow path are affecting Natural ventilation performance [11].

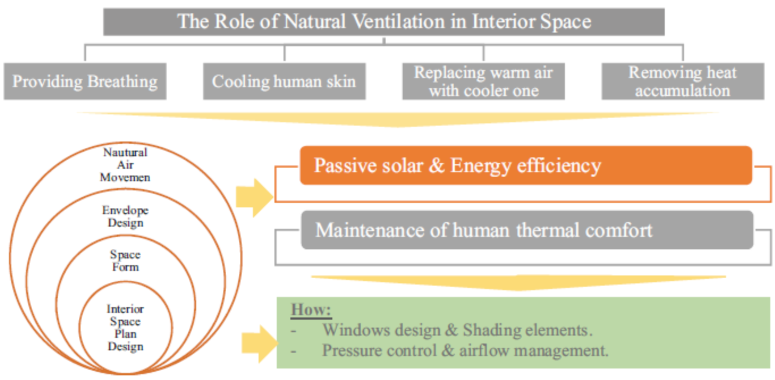


Figure 3: spatial driven force for natural ventilation inside interior spaces [28]

8.2. Spatial Configuration and Thermal Comfort

One of the most important passive cooling strategies is Spatial design. As it helps in cooling down the microclimate by two ways: natural ventilation and solar control. spatial configurations influence has binary edges: firstly, it can affect building microclimate in a direct way as it can cool down the building microclimate in summer. Secondly, it provides an adaptive opportunity for the comfort of occupants which is strongly affect thermal comfort in the summer [29,30] as shown in **Figure 4**.

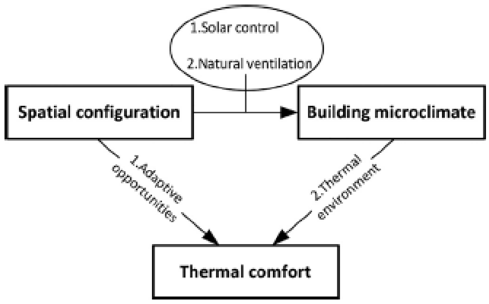


Figure 4: spatial configurations, building microclimate and thermal comfort [29].

8.3. The Potential of the Space Syntax Method for the Preliminary of Airflow Analysis

It is assumed that the space syntax analysis method is a "space interpretation" method. To reveal the impressions of the "spatial look" and their social interactions for structures and structured contexts Bill Hillier and his team in the early 1970s theoretically launched space syntax analysis method in the fields of architecture and urbanism. According to their theory, space is represented by its parts, to form a network of related components [31].

People's movement patterns, wayfinding behaviors, and route choices can be predicted in a specific spatial configuration of a building or of urban morphology using space syntax analysis. However, in this study, the focus of the space syntax analysis is shifted to air flows.

The assumption is that common features of people flow, and air flows are related to spatial configuration. The space syntax method has demonstrated the importance of spatial accessibility and permeability for people's movement. The focus of ventilation performance analysis is on air movement patterns. Pressure differences and wind are the driving forces of air movement between spaces, including both outdoor and indoor spaces. The magnitude and direction of these forces, as well as the flow resistance of the flow path, influence ventilation rates. As a result, spatial accessibility, and permeability, which are important for people flows, are also important for air movement between spaces so the connectivity value appears.

- The connectivity value describes the total number of spaces which are directly connected to a particular space. As connectivity value increases the permeability of the space increases [32].
- The integration value describes the positive correlation of the accessibility of a particular node in a space configuration. The bigger a node's integration value, the better the relative permeability and accessibility of this node in the relevant spatial configuration.

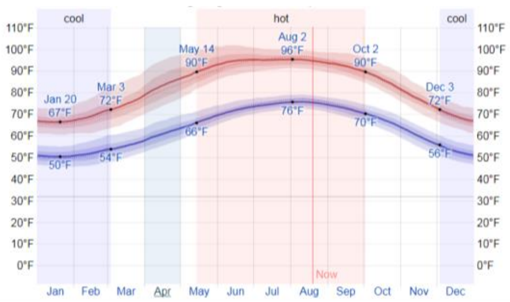
9. CASE STUDY

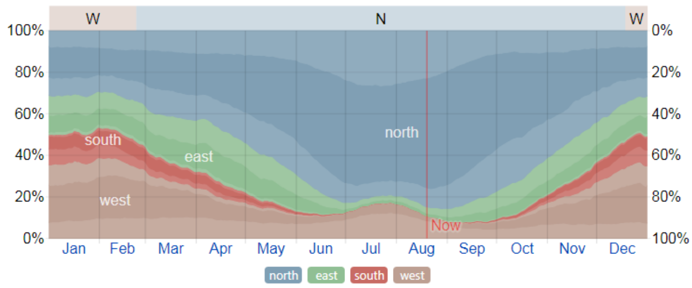
Due to the social and economic factors that face low-income group in Egypt they can’t bear housing, Thus the government provides suitable housing for this group to overcome their problems. The case study located in El-SHOROUK city as shown in **Figure 5**. It established under Presidential Decree No. 326 of 1995 in term to reduce the population increase in Greater Cairo by creating points of attraction for developers. It located on the northeast of Cairo. It is on a vital road that easily connects the city to both the New Capital and Greater Cairo. It is surrounded by two main roads Ismailia Desert Road and Cairo Suez Desert Road [33].

Figure 5: Case study location source: Author.

9.1. Weather Data

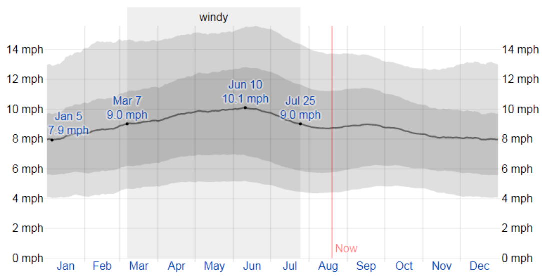
According to Köppen classification Cairo region is classified as Bwh climate, this climate classification is defined as hot arid climate. It featured with hot-dry summer, the maximum temperature is 45°C and the whole year has non-broken sunshine [34]. According cairo_ETMY based on the stations at Cairo international airport and Alexandria Borg El Arab airport as shown in **Figure 6**, in Cairo the average annual air temperature is 72 ºF (22ºC), the highest annual mean air temperature is in August with 96ºF (35ºC), and the lowest annual mean air temperature is in January with 50ºF (10ºC) as shown in. The prevailing wind direction in Cairo is often from north with peak percentage 86% in August and often from west for peak percentage 35% in January, the most average wind speed in Cairo is 10.1 mph in June and the lowest average wind speed is 7.9 mph in January [35].

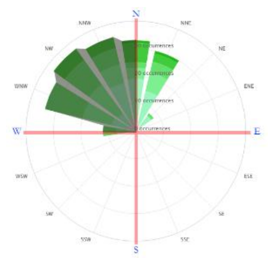




a) Average annual temperature in Cairo

b) Wind direction in Cairo





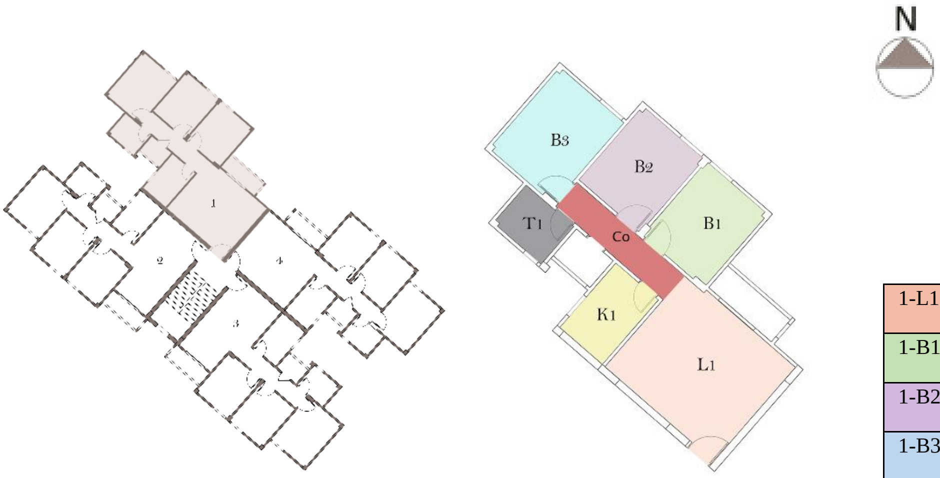
c) Average annual wind speed in Cairo

d) Wind rose of Cairo

Figure 6: Weather data for the selected case study [35].

9.2. Case Study Description

The selected prototype is a social housing residential-symmetric-six-levels building with 3 m height of each level. It consists of 4 apartments each of 90 m2 area with 1 living room, 3 bedrooms, a kitchen, and a bathroom. The study will be on unit number 1 as shown in **Figure 7**. The Prototype social housing is a group of units built by the Egyptian government first started in 2012 and has specific shapes and building layout geometries and approved by the Egyptian Housing and Building National Research Centre (HBRC). The design of this prototype is fixed neglected the weather or the location.



1-L1	Living Room
1-B1	Bedroom 1
1-B2	Bedroom 2
1-B3	Bedroom 3
1-T1	Toilet
1-K1	Kitchen
1-Co	Corridor

Figure 7: Layout for the selected case study source: Author

The selected residential unit for study is in the 2nd floor unit as it doesn't have the special thermal behavior as ground and the last floor units due to direct-to-earth conduction, and solar exposure. For the VGA and spatial analysis each space will considered as a node which has its own configuration and dimensions, the unit dimensions and parameters in **Table 2.**

Table 2: The base case dimensions and parameters.

Selected Unit Parameters			Doors Parameters		
Floor Level		2nd Floor Level (+10.17 m level from zero level)	3 Doors for bedrooms	Width	0.90 m
				Height	2.20 m
Area		90 m^2	2 Doors for kitchen and toilet	Width	0.80 m
Dimensions				Height	2.20 m
Node	Space Name	Dimensions	1 Sliding door for balcony	Width	1.60 m
				Height	2.20 m
1-L1	Living Room	4.3*5 m	1 door for balcony	Width	0.80 m
				Height	2.20 m
1-B1	Bedroom 1	2.8*3.4 m	Windows Parameters		
1-B2	Bedroom 2	2.8*3.4 m	3 Windows for bedrooms	Width	1.00 m
				Height	1.20 m
1-B3	Bedroom 3	2.8*3.7 m	Kitchen window	Width	0.90 m
				Height	0.60 m
1-T1	Toilet	1.7*2.2 m	Toilet window	Width	0.60 m
				Height	0.60 m
1-K1	Kitchen	3.0*2.0 m	W.W.R	12.3%	
1-CO	Corridor	1.1*4.93 m			

9.3. Space Syntax Analysis

In this study the program Depthmap10 used to perform the visibility graph analysis (VGA). The studied layout divided In the VGA analysis into multiple rectangular spaces (squares) using a grid set to (200 mm * 200 mm) which is determine the result accuracy. The main parameters which related to the spatial features of each square is shown in VGA map. In this case, the focus is connectivity parameter. A special aspect of this study that VGA analysis includes the outdoor environment. So, the outdoor space represented as one node. the space syntax analysis focuses on the spatial relation between indoor spaces only. But in this case, the focus is on the spatial connectivity between indoor spaces and outdoor one. Because the permeability is significant mainly for the wind environment and air movement between indoor spaces and outdoor one. It is noted that this plan outlines only the spatial relations as shown in **Figure 8**.

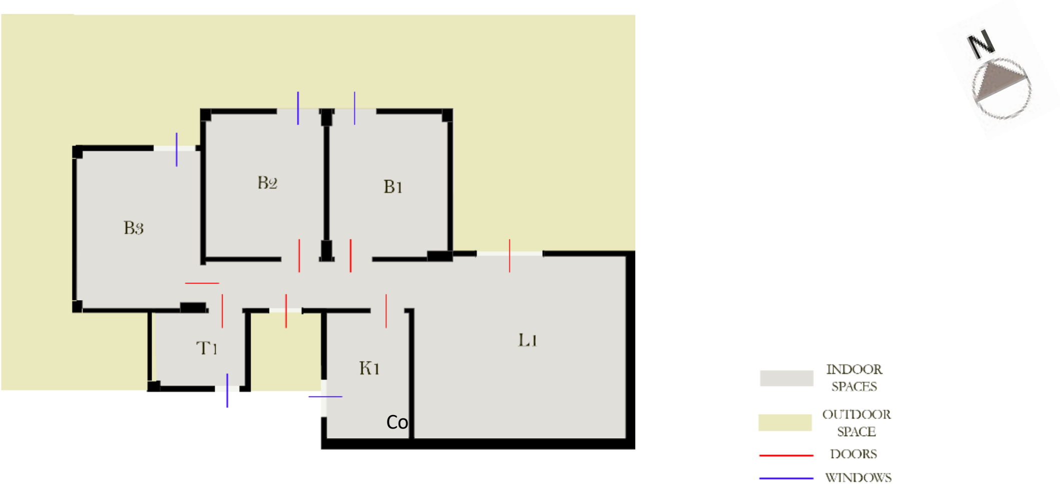


Figure 8: Layout for the spatial analysis source: Author.

The outside boundary of the building is extended to include wind environment in this VGA analysis. So as the outside boundary extended the potential of natural ventilation inside the building in this analysis is greater. for more accurate results the boundary is more extended on the side that respecting the wind direction as shown in Figure 6(d) the prevailing wind in Cairo is on the north and north-west side. So, to respect the wind direction the boundary is larger on north-west side than other sides. **Figure 9** shows the outside wind environment boundary settings of the test. It is assumed that the total length of the building is L so the boundary is extended 0.5L north and 0.5L north-west.

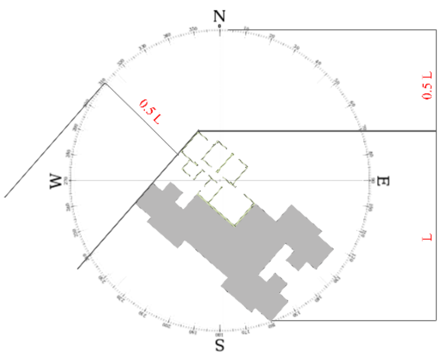


Figure 9: the outside wind environment boundary for the VGA analysis source: Author.

9.4. CFD Model

The wind velocity is measured on the studied floor. Design builder software was used for a CFD simulation for the studied residential unit. The operation of the unit is free running with using natural ventilation and without any using of mechanical heating and cooling in the simulation period. The doors and windows were opened completely.

10.RESULTS

10.1. Space Syntax Analysis Results, VGA Method

The visibility graph analysis (VGA) grid was set to 200x200mm for the studied layout. Every square (200x200mm) is considered as a node. the visibility graph analysis (VGA) map calculates and illustrates the connectivity and integration of every square as shown in **Figure 10**.

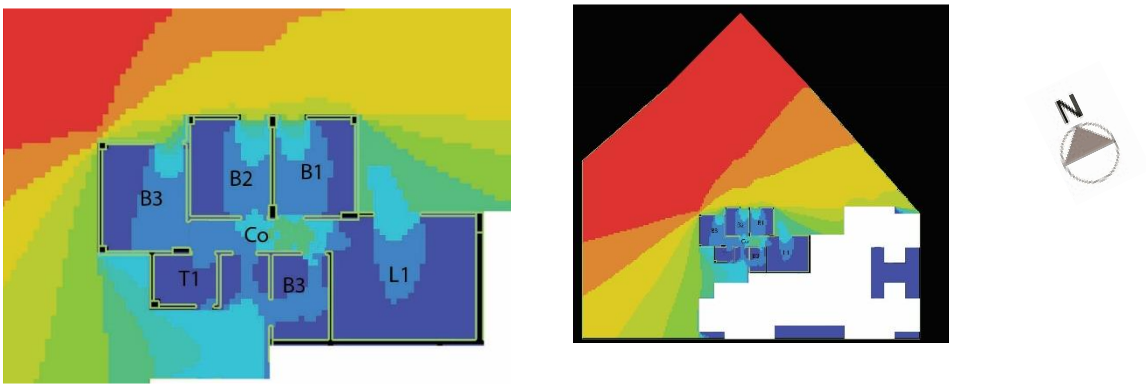


Figure 10: The VGA map of the connectivity value relative to the floor plan (the arrow represents the wind direction; from red to deep blue, the connectivity is from big to small) source: Author.

It was found that the distribution of the connectivity values in the plan are similar. Most of the area in the Corridor has a very high connectivity value compared with other spaces, followed by part the area of the bedrooms and the kitchen then living room. The value in the toilet is very low. This indicates that the permeability and accessibility in the corridor then the bedrooms are better, followed by the kitchen.

10.2. CFD Simulation Results and Wind Velocity Measurements

Figure 11 shows the wind field map at the 13:00 of June 21 on the second floor through the CFD simulation. The wind velocity is not high at that moment, but in this research, the more focus is on the distribution of wind velocity. It is easy to find that the wind velocity in the corridor is the biggest and the kitchen. Comparing the simulated wind velocity shows that, the wind velocity in the corridor and kitchen are the biggest which is between (0.09 m/s and 0.06m/s), second is the point in the bedrooms (0.04 m/s) and the lowest is the living room and toilet which is between (0.03m/s and 0.01 m/s). The result of simulation shows that it is relative easier to obtain enough wind velocity in the corridor, kitchen, and bedroom than in the living room and toilet.

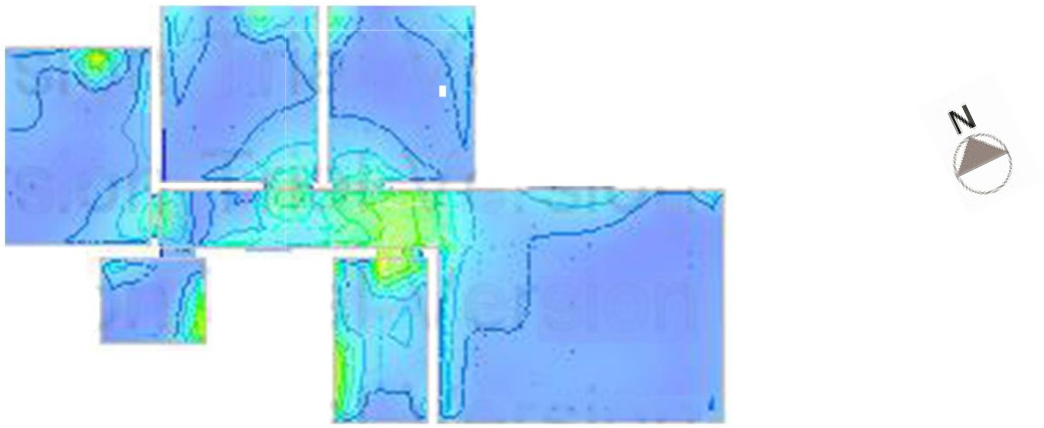
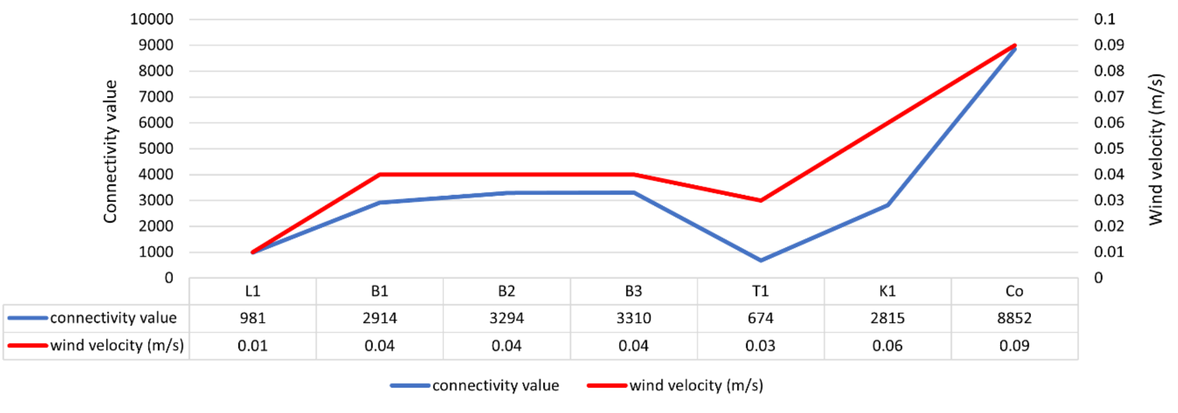


Figure 11: Simulated wind velocity map source: Author.

10.3. Comparing Results

In the space syntax analysis, the results show that the permeability and accessibility of the corridor is better than other spaces. The simulation results show the wind velocity in the corridor is bigger than other spaces. Comparing the results, it was found that the results of simulated wind velocity can be matched with the spatial analysis in terms of the trend of wind velocity distribution is matched with the connectivity and integration distribution. We can get this conclusion from **Figure 12** which shows a comparison between simulated wind velocity and VGA result. The two results were matched. comparing the VGA result and CFD simulated result it was found that in the corridor, the connectivity and integration value are bigger, also the wind velocity is bigger in compare with other spaces. While in toilet and living room the connectivity and integration value are the least comparing to other space and the wind velocity in those spaces are least comparing to other spaces. So, we can say that the spatial permeability and accessibility have similar characteristics as the air movement in the building which is indicated by wind velocity.



	L1	B1	B2	B3	T1	K1	Co
connectivity value	981	2914	3294	3310	674	2815	8852
wind velocity (m/s)	0.01	0.04	0.04	0.04	0.03	0.06	0.09

Figure 12: The connectivity value and simulated wind velocity per each room source: Author.

11. CONCLUSIONS

Only one layout of a low-cost residential building analyzed in this paper through space syntax approach coupling with CFD analysis and it found that:

- There is a great potential to use the space syntax approach in order to predict the air movement which help architects to predict the performance of natural ventilation in an easily way in early design stage.
- Using space syntax analysis helps architects to get the more suitable layout configurations that enhance the performance of natural ventilation without using more techniques after the construction process finishes.
- The space having high connectivity value has the potential to achieve more air flow, especially through cross ventilation. Not only in building scale but also in room level. So, spaces which have good permeability provide the potential of air movement through spaces well.

12. LIMITATIONS

- As the behavior of Ventilation in buildings is considered as a complex one where many factors are related. There are many simplifications have done in this study for the analysis. The actual wind velocity, air flow rate, wind pressure and the air temperature cannot be predicted through The space syntax method. it only can show the potential of a particular spatial configuration to achieve the natural ventilation.

13. RECOMMENDATONS

- In further, studying more residential building layout with different s to reveal the underlying relationship between the spatial configuration and wind to predict the trend of natural ventilation in the design practices.
- Studying the effect of different building design parameters as changing building orientations, using different opening sizes to get the optimum configuration to enhance air flow.
- Coupling space syntax with another methods as daylighting techniques can support the design process and influence the decision making.

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