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Bio-climatic Strategies for Semi -Arid Zones: Aligning Geometry with Climatic Forces in Wapda Town and NFC Society, Lahore

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ABSTRACT

The Urban population is increasing densely in Pakistan specially in large cities as people are migrating from Rural to Urban areas for broader life prospects. Lahore has the second highest population and according to research, its population will increase 75% by 2030 due to urbanization (Abbasi, Jabeen, and Khalid 2022).This increased flux of people is imposing load on urban amenities & infrastructure, causing them to be densely populated, more polluted & less sustainable. Primarily responsible for global warming and causing serious health issues, which exacerbate urban heat island (UHI) phenomenon and increase the regional temperature trends (Givoni 1998).In order to escape from this devastating situation, designers need to adopt design considerations which cater to the environment. Bio-climatic approach for urban design & planning can be the solution, where design of urban centers will affect the micro climate of the area to ensure sustainable development as well as energy efficient dwellings. Bio-climatic Urban Design is categorized into Geometric Structure, Vegetation and Construction with different coating materials. In this paper, the aim is to study the effect of aligning urban geometry with Wind, one of the factors affecting the energy budget of a human being and to generate "Guidelines for bio-climatic urban design for cities in hot, semi-arid climate". The afore mentioned objective is achieved by the method of critical analysis of literature review. In order to proceed this research, main avenues of two LDA approved society has been taken as a case study to implement the required changes.

Introduction

Sustainability has become a course of discussion around the globe recently. In hot climate areas about 40% to 50% of the energy resources are utilized for cooling purposes (Amer, Boukhanouf, and Ibrahim 2015) as some state it to be 60% (Saeed, Ahmed, and Butt 2013). Buildings in Pakistan are generally built with brick wall with low to moderate insulation, putting all the responsibility of cooling a space on active cooling. As Pakistan is a member of Paris Agreement of 2015, it is important for us to control our Carbon emissions, by using passive techniques for cooling.

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The foundation of design for thermal comfort is grounded in understanding the energy budget of a person, which refers to the balance of energy intake and expenditure of the human body. Input is the amount of energy a person absorbs, whereas output is the amount of energy a human body releases in the environment. The internal body temperature of a person should range from 36 C to 38 C (Geneva et al. 2019). If the temperature goes up it is known as hypothermia, and if it goes down it is known as hyperthermia (Doshi and Giudici 2015). The human body uses the process of convection, evaporation, conduction and radiation for the energy exchange. There are 7 main factors that affect the energy budget of a human being including air temperature, wind, solar radiation, terrestrial radiation, metabolic heat and clothing insulation. The first five parameters were affected by the urban environment, whereas the other two are relate
to the personal choice of the people. The first two factors are conservative at micro scale, because the air temperature changes at the height of 1.5 meter above the ground and changes very little over short distance. The most effective factors are wind, solar radiation and terrestrial radiation. Keeping in mind, the above needs of human energy exchange, the urban design should be Bio-climatic in nature, so that the densely populated areas can be protected from the harmful effects of heat waves (Mazhar et al. 2015). In this paper the focus area will be wind and its alignment with the urban geometry, as it is one of the most important factors effecting the human energy budgeting.

Climate Conditions

Pakistan is the sole nation in the entire world that has a unique altitude range from sea level to the second highest mountain peak in the world. This aspect makes it have a tremendous fluctuation in climate from region to region. The climate of Pakistan is mostly dry with hot summers and freezing winters. Much of Pakistan is semi-arid and arid, while in some regions it is hyper-arid in the lower south of the nation. There are four distinct seasons of climate in the nation(Khan 2010) . Lahore is in the semi-arid zone.

Bioclimatic Chart of Lahore

This diagram for analyzing the comfortable climatic conditions for living was explained by the Olgyay's Brother in 1950's. This chart shows the relationship of different climatic elements with one another. The natural human thermal comfort zone where no external resources are required of heating or cooling is mentioned in the middle of the diagram. The method is to gain temperature data of all months of the year and then plotting it
according to the average humidity. The thermal comfort zone diagram of Lahore (figure 1),

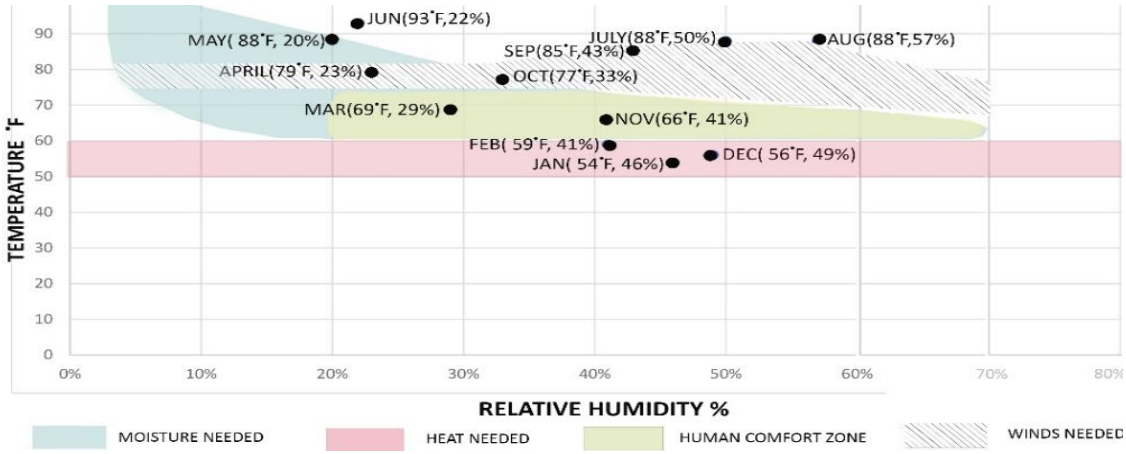

Figure 1 Bioclimatic chart of Lhore

Shows the climate conditions in all 12 months in Lahore. The months of January (54ºF, 46%), February (59ºF, 41%) and December (56ºF, 49%) needs heating. The month of March (69ºF, 29%) and November (66ºF, 41%) are comfortable months which do not need any heating or cooling. The months of May (88ºF, 20%) and June (93ºF, 22%) needs humidity. The months of April (79ºF, 23%)

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and October (77°F, 33%) needs humidity and wind whereas the months of July (88°F, 50%), August (88°F, 57%) and September (85°F, 43%) needs winds only. This shows that total number of hot months that require active cooling are seven and out of it five require integration of winds. This shows the importance of wind incorporation for generating microclimate and controlling the human energy budgeting.

Material and Methodology

In order to carry out this research, the methodology integrates both insight from the critical literature review and quantitative analysis incorporating established mathematical formulas to investigate the ratios of urban geometrical structures to wind orientation for semi-arid climate. Keeping Lahore as a prototype. The analysis is completed by using secondary data from articles, and then applying the formulas on two small societies in Lahore city.

Urban Geometry with Reference to Wind Orientation in Semi-Arid Regions

Geometrical structures in the urban fabric are the buildings and their effect on the factors that affect the energy budget of the humans. These features incorporate, street networks, street patterns, urban blocks, voids, urban edges, the aspect ratio of building heights and the orientation, have the most significant influence. Instead of thinking for a specific building, we are focusing on the urban design of specific climatic conditions. I have already discussed Lahore's weather so taking it as a prototype, to highlight the optimal solutions. The notion revolves around building a Climate Responsive Design, focusing on wind.

The roads and streets act as corridors, from where the wind passes, so it eventually describes the urban climate of the entire urban area. If street patterns are not wisely defined, it could be limitation to design. Long and deep streets are present, these streets have aspect ratio and are called ''**Urban canyons.''** Urban canyons are the urban buildings up to their roofs and the volume of air affected by the urban environment is called **urban boundary layer or urban air dome** (Givoni 1998)**.** The formula to investigate, if the urban canyon is suitable or not is known as aspect ratio.

Aspect ratio = Height of the building/ Width of the streets (Oke 1988)

Aspect Ratio = Average Length / Average height of Building

It is stated in the literature review that the aspect ratio greater than 1 is considered best, as it provides deep shadow for pedestrians. If the canyon is uniform, its aspect ratio will be equal to 1. Shallow canyon will have aspect ratio below 0.5 and deep canyon will be equal to 2. Whereas if we are using the other formula, it will be considered as a short canyon when the value of the aspect ratio is 3. It will be a medium canyon when its value is 5 and long when its value is 7 (Ahmad, Khare, and Chaudhry 2005)

Orientation of Wind to the Urban Canyon

The angle of wind flow within the urban canyon, to the canyon axis is future divided into three categories. In normal orientation of the wind canyon, the wind direction is perpendicular to the canyon axis. In oblique orientation the wind will form spiral vertex along the canyon length. In parallel orientation, the wind flow is parallel to the canyon axis and it penetrates into the heart of the urban area. It is the obstruction free passage way for the wind to flow.(Santamouris, Georgakis, and Niachou 2008)

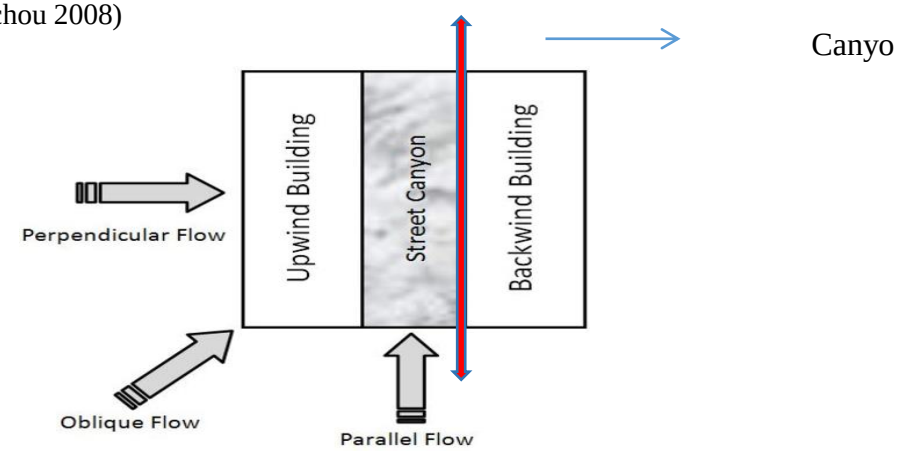

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Figure 2 Wind direction angles to the canyon axis

Prototype Sites in Lahore

The societies taken as prototype for the study of Lahore and its guidelines for bio-climatic urban design for wind are **Wapda Town and NFC Society Lahore.** Both the socialites are under LDA (Lahore Developmental Authority).

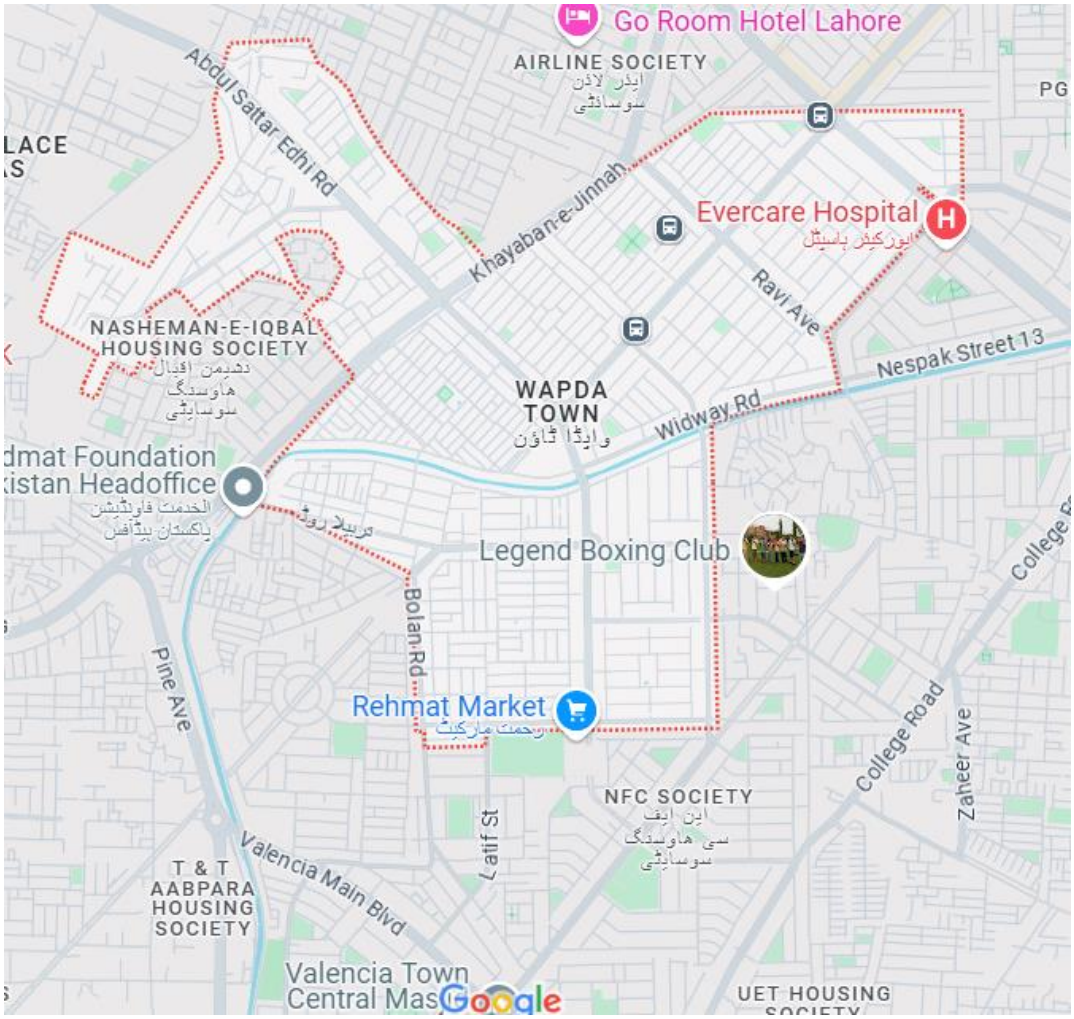

Figure 3 Map of Wapda Town And NFC Society lahore

Wapda Town Lahore

The main road of Wabda Town Society is taken for the analysis of orientation of wind to the urban canyon.It is a mixture of commercial with three to four floors.In figure 4 are commercial zones with height around 36 feet to 48 feet respectively.The average of these floors will be 42. The main road running in between these commercial buildings is about 75’ in width.

Existing Aspect Ratio Analysis of Site

The existing Aspect Ratio of Wapda Town main road with reference to wind, as the main road of this society is 75 feet in width and building height 42 feet will be

Aspect ratio = Height of the building/ Width of the streets
= 42/ 75 = 0.56.

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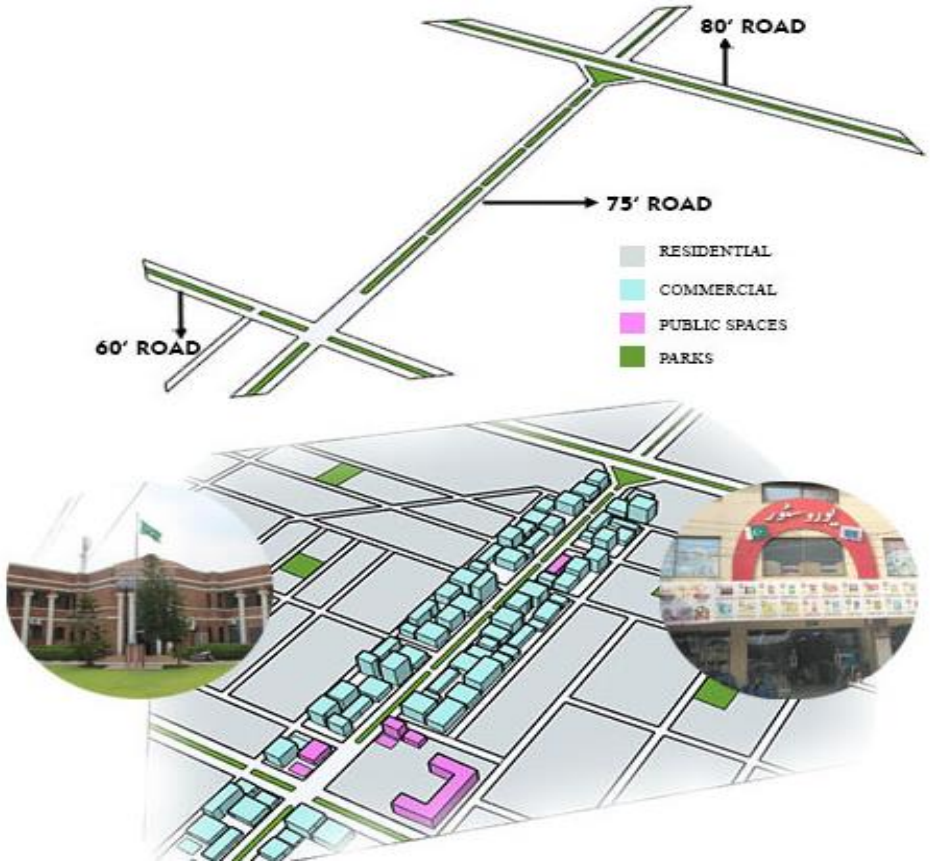

Figure 4. Map Of Wapda Town, Lahore

The aspect ratio of the society should be greater than 1, to make the wind orientation with respect to geometric structures work effectively.At present it is shallow canyon.

Proposal 1

To get the required aspect ratio which is greater than 1, and considering the wind analysis data, we can increase the height of commercial area by some floors, to get desired height of 84 feet if the road width that is 75 feet is kept as it is.

Aspect ratio = Height of the building/ Width of the streets

= 84/ 75

= 1.12

Proposal 2

To get the required aspect ratio which is greater than 1, and considering the wind analysis data, if we cannot increase the height of commercial area, instead decrease the width of the road to from 75 feet to 40 feet.

Aspect ratio = Height of the building/ Width of the streets

= 42/ 40

= 1.05.

Proposal 3

To get the required aspect ratio which is greater than 1, and considering the wind analysis data, we can increase the height of commercial area by some floors, to get desired height of 48 feet. Also, to increase wind velocity, narrow street works better than the wider ones, leading to decrease of main road width from 75 feet to 50 feet.

Aspect ratio = Height of the building/ Width of the streets

= 48/ 50

= 0.96 (approximately 1)

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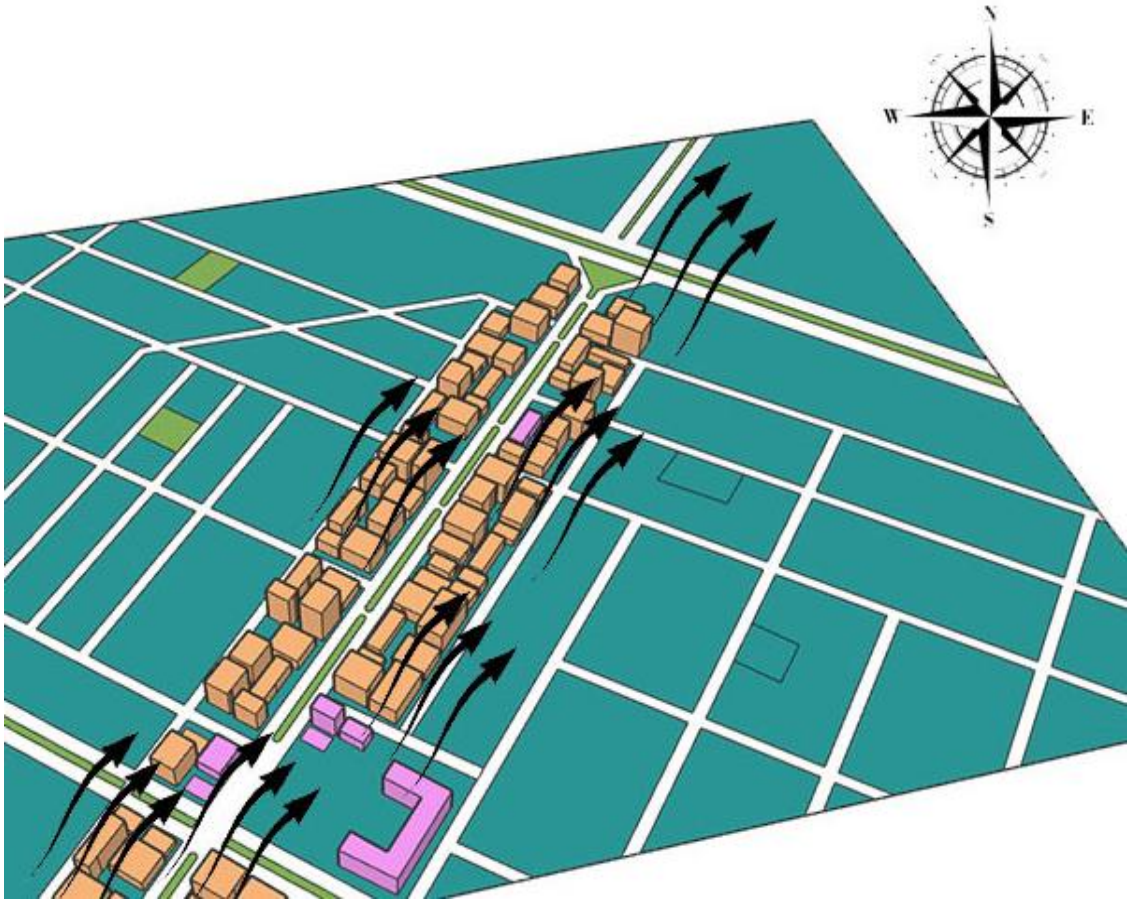
As a result, aspect ratio greater than 1 will provide, Deep Canyon. These proposals are some of the examples from which the desired ratio can be obtained.

Existing Site Wind Orientation

The orientation of wind of Lahore is South-West to North-East. According to the wind direction of the Wapda Town Society, orientation of the wind type is Parallel. It means it is at Parallel angles with the canyon axis, which means that the velocity of the wind is maximum. Changing the orientation of Wapda town main road is not required.



The Figure 5. Existing Wind Direction Of Wapda Town

Nfc Society Lahore

The main road of NFC Society is taken for the analysis of orientation of wind to the urban canyon.the height of the buildings are around 60 feet mostly consist of five floors in total. The main road running in between these commercial buildings is about 80 feet in width.

Existing Aspect Ratio Analysis of Site

The existing Aspect Ratio of NFC Society with reference to wind, as main road of this society is 80 feet in width and building height ,60'.

Aspect ratio = Height of the building/ Width of the streets

= 60/ 80

=0.75.

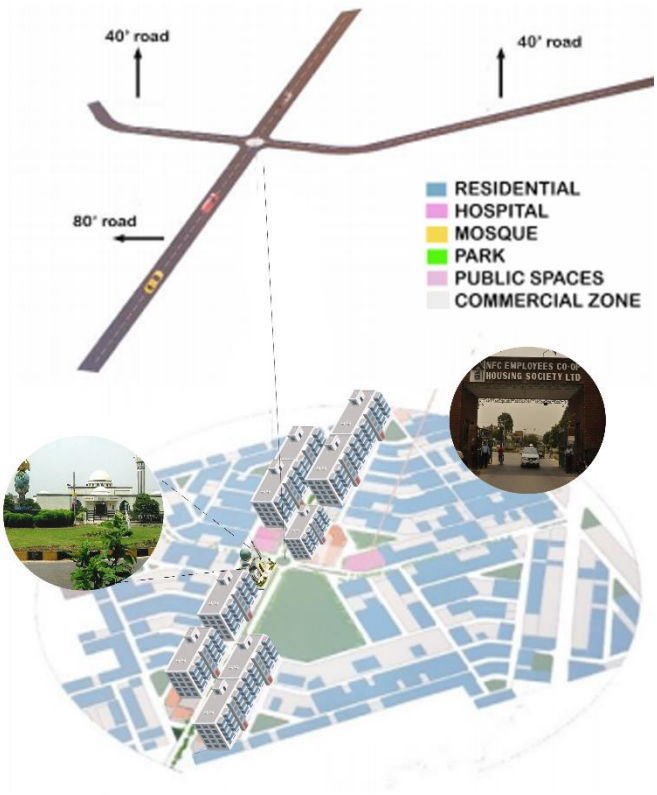


Figure 6 Map Of NFC Society,Lahore.

The aspect ratio of the society should be greater than 1, to make the wind orientation with respect to geometric structures work effectively.

Proposal 1

To get the required aspect ratio which is greater than 1, and considering the wind analysis data, we can increase the height of commercial area by some floors, to get desired height of 84'with road 80' wide.

Aspect ratio = Height of the building/ Width of the streets

= 84/ 80

= 1.05

Proposal 2

To get the required aspect ratio which is greater than 1, and considering the wind analysis data, if we cannot increase the height of commercial area, instead decrease the width of the road to 50'.

Aspect ratio = Height of the building/ Width of the streets

= 60/ 50

= 1.2.

Proposal 3

To get the required aspect ratio which is greater than 1, and considering the wind analysis data, we can increase the height of commercial area by some floors, to get desired height of 63'. Also, to increase wind velocity, narrow street works better than the wider ones, leading to decrease of main road width from 80' to 62'.

Aspect ratio = Height of the building/ Width of the streets

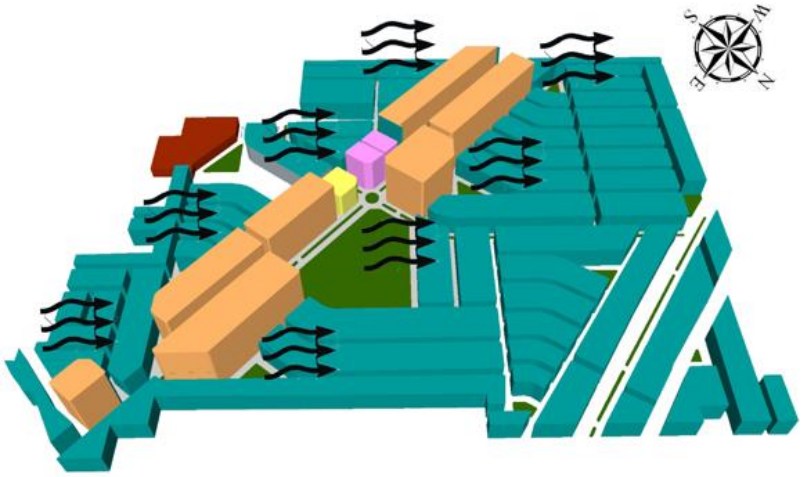
= 63/ 62

= 1.01

As a result, aspect ratio greater than 1 will provide, Deep Canyon. These proposals are some of the examples from which the desired ratio can be obtained.

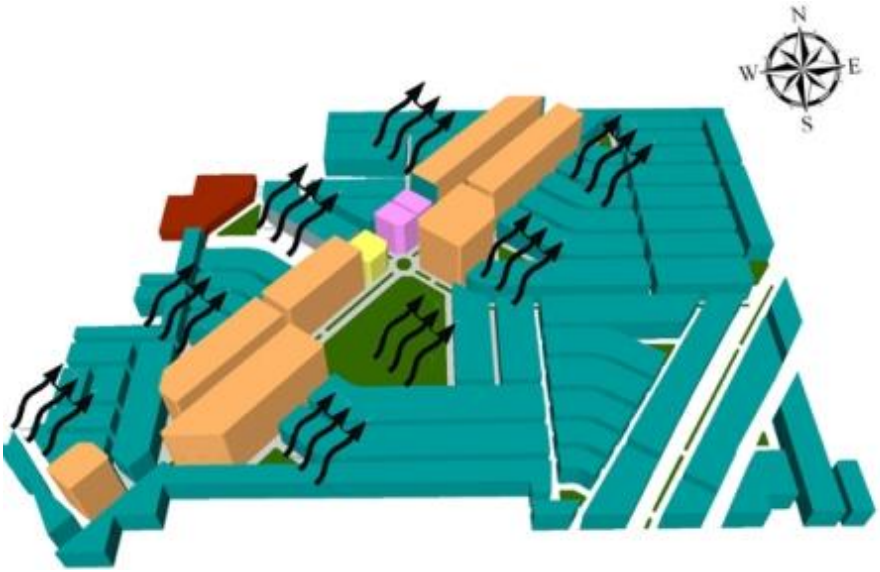
Existing Site Wind Orientation

The orientation of wind of Lahore is South-West to North-East. According to the wind direction of the NFC Society, the orientation of the wind type is oblique. It means it is at diagonal angles with the canyon axis, which means that spiral vertices of wind are formed along the canyon's length. To avoid that, we have to increase the width of road.



Proposed Solution

Changing the orientation of NFC society, parallel to the canyon axis. According to the research, the most effective type of wind orientation is Parallel type. That the wind moves along the wind corridors.So, the idealistic, direction of N, will be shown in the figure .



Conclusion

After this analysis, it can be concluded that urban geometry/geometrical structure, has a significant effect on the outdoor thermal climate of urban fabric. Also, the characteristics of wind such as aspect ratio & wind direction also play an important role. Different strategies have been discussed for a housing society Wapda town and (NFC) in Lahore. Considering wind as a source to create Bio-climatic design solutions for the studied area. While proposing desired orientation of the plots according to wind direction has been kept in mind as well. In the studied areas corridors for the uninterrupted passage of wind are suggested, parallel to the Canyon axis as direction of the wind in

Lahore is i.e. SW to NE. By proposing these strategies, the wind canyon area of this particular urban fabric is also increased.

Refrences

Abbasi, Nida Qanber, Asia Jabeen, and Maliha Khalid. 2022. "Urban Generosity: Strategies for Rejuvenation of Historic Site-Mughal Tombs of Shahdara." *Pakistan Languages and Humanities Review* 6 (4): 282–95.

Afiq, WMY, CS Nor Azwadi, and KM Saqr. 2012. "Effects of Buildings Aspect Ratio, Wind Speed and Wind Direction on Flow Structure and Pollutant Dispersion in Symmetric Street Canyons: A Review." *International Journal of Mechanical and Materials Engineering* 7 (2): 158–65.

Ahmad, K, M Khare, and KK Chaudhry. 2005. "Wind Tunnel Simulation Studies on Dispersion at Urban Street Canyons and Intersections—a Review." *Journal of Wind Engineering and Industrial Aerodynamics* 93 (9): 697–717.

Amer, O, R Boukhanouf, and HG Ibrahim. 2015. "A Review of Evaporative Cooling Technologies." *International Journal of Environmental Science and Development* 6 (2): 111.

Doshi, Hardik H, and Michael C Giudici. 2015. "The EKG in Hypothermia and Hyperthermia." *Journal of Electrocardiology* 48 (2): 203–9.

Geneva, Ivayla I, Brian Cuzzo, Tasaduq Fazili, and Waleed Javaid. 2019. "Normal Body Temperature: A Systematic Review." In , 6:ofz032. Oxford University Press US.

Givoni, Baruch. 1998. *Climate Considerations in Building and Urban Design*. John Wiley & Sons.

Khan, Saif Ullah. 2010. "CLIMATE CLASSIFICATION OF PAKISTAN."

Mazhar, Naveed, Robert D Brown, Natasha Kenny, and Sanda Lenzholzer. 2015. "Thermal Comfort of Outdoor Spaces in Lahore, Pakistan: Lessons for Bioclimatic Urban Design in the Context of Global Climate Change." *Landscape and Urban Planning* 138:110–17.

Oke, Tim R. 1988. "Street Design and Urban Canopy Layer Climate." *Energy and Buildings* 11 (1–3): 103–13.

Saeed, Fariha, Syed Tauseef Ahmed, and Arif Qayyum Butt. 2013. "Simulation of Electricity Consumption for Newly Built Residential Buildings in Lahore." *J. Res. Archit. Plan* 14:55–60.

Santamouris, Mattheos, Chrissa Georgakis, and A Niachou. 2008. "On the Estimation of Wind Speed in Urban Canyons for Ventilation Purposes—Part 2: Using of Data Driven Techniques to Calculate the More Probable Wind Speed in Urban Canyons for Low Ambient Wind Speeds." *Building and Environment* 43 (8): 1411–18.

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