The Study of the Relationships between Building Arrangements and Climatic Comfort

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Abstract**—**The Abu Dhabi Master Plan 2030 is the UAE government's vision to establish Abu Dhabi as an international capital city and is based on sustainable development principles. The master plan includes several districts with distinct characteristics: a business district, capital district, Emirati residential district, etc., where landmarks, generally located around plazas and open spaces, are an important component. The actual arrangement of buildings was not proposed in the master plan, and the more detailed design guidelines and orientation were left to be considered in the urban design phase. This research project studies which building arrangement will provide the maximum climatic comfort, not only for the buildings, but also in and around the surrounding open spaces. The goal of this study is to maximize the use of these spaces, by increasing walkability and encouraging social interaction in compliance with the vision of the plan and the sustainable development principles mentioned earlier.

Keywords**—**Abu Dhabi Master Plan 2030, building arrangements, climatic comfort, open spaces, shadow

I. Introduction

TWO main seasons are dominant in the UAE climate, namely the winter, which is the cold period season from December until mid-March, and the summer season, which is the hot period from the second half of June through September. The transitional periods are spring and autumn respectively." (Physical Geography of Abu Dhabi Emirate).

The hardest days are when the humidity is above 70% and temperatures are above 35°C. The humidity pattern values are almost the same every day, after midday it starts a gradual increase over a few hours to reach values of 70-80%. It then declines to 35-50% by the midday hours. (Physical Geography of Abu Dhabi Emirate).

We cannot start our study without talking about the longest and shortest days of the year.

In the UAE, the longest day is the 21st of June and the shortest is 21st of December. On the 21st of April and 22nd of September, the day and nights are equal. The monthly mean of the daily sunshine hours is similar all over the Emirate, and ranges between 8.4 hours in winter, to 11.6 hours in summer. These values accumulate total sunshine hours of about 3,600 hours per year, which is among the highest found around the world." (Physical Geography of Abu Dhabi Emirate).

Regarding the wind, In general, the prevailing wind direction is mainly from the northwest." (Physical Geography of Abu Dhabi Emirate).

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II. Research Objective

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III. Site Selection

One of the main objectives of this research is to propose building arrangements that contribute to the creation of comfortable microclimates, particularly in summer, by reducing the outdoor temperature through the production of designs giving the maximum shaded areas. To facilitate this objective, it was important to select a site that has not yet been built in order to check the urban design guidelines, particularly the building height and to thus propose a building arrangement that could be adopted later for the selected site. In this context the the Abu Dhabi Master Plan 2030 that covers among other items the future capital city's (Fig. 1) development with its urban design guidelines represent a good urban planning document, from which to choose the two sites that are located in the South Spine, one of the six precincts of the Capital District as per (Fig. 2). The South Spine is designed to include different land uses and building heights, which make it a good area for site selection.

Two open spaces were selected with different shapes, one triangular: Site A and the other rectangular: Site B (Fig. 3) in order not to limit the shape of the site to one shape.

The surrounding area has different land uses and building heights, so that any proposed building arrangement will test

more than one criterion at each simulation time. The setback will however remain constant as stipulated in the master plan and a minimum distance between buildings was respected for privacy purposes.

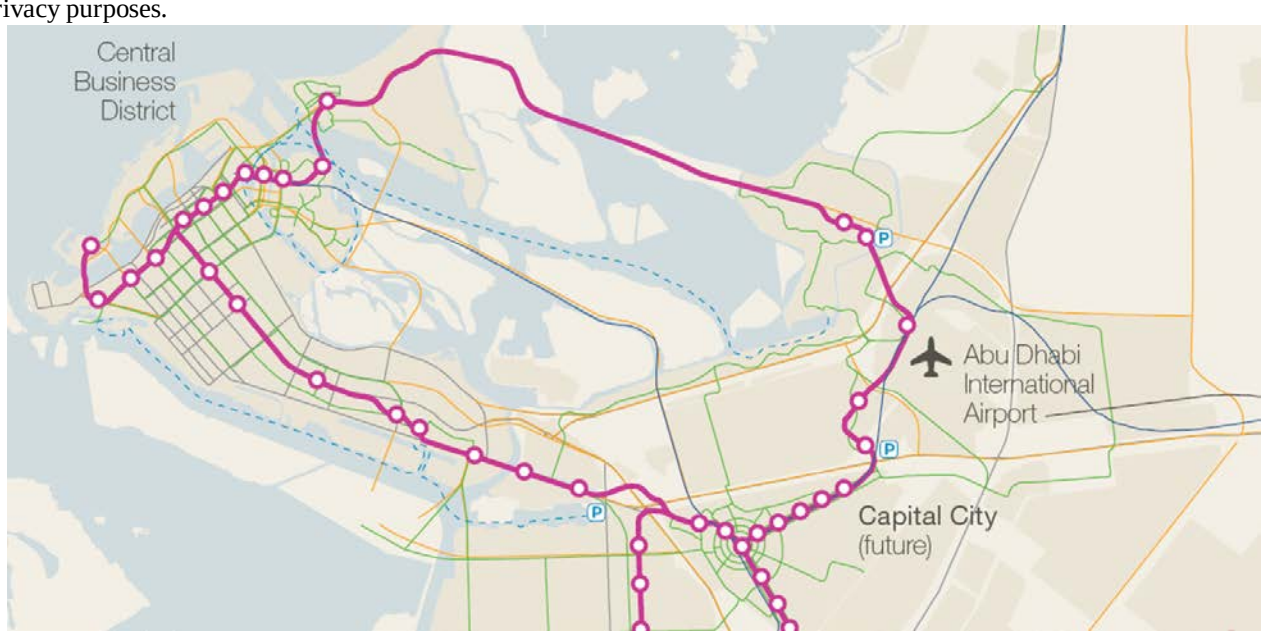

Fig. 1 Location of the future Capital District of Abu Dhabi
Source: ABU DHABI URBAN PLANNING COUNCIL. *Plan Abu Dhabi 2030- Urban Structure Framework Plan*, Abu Dhabi, UAE, 2007

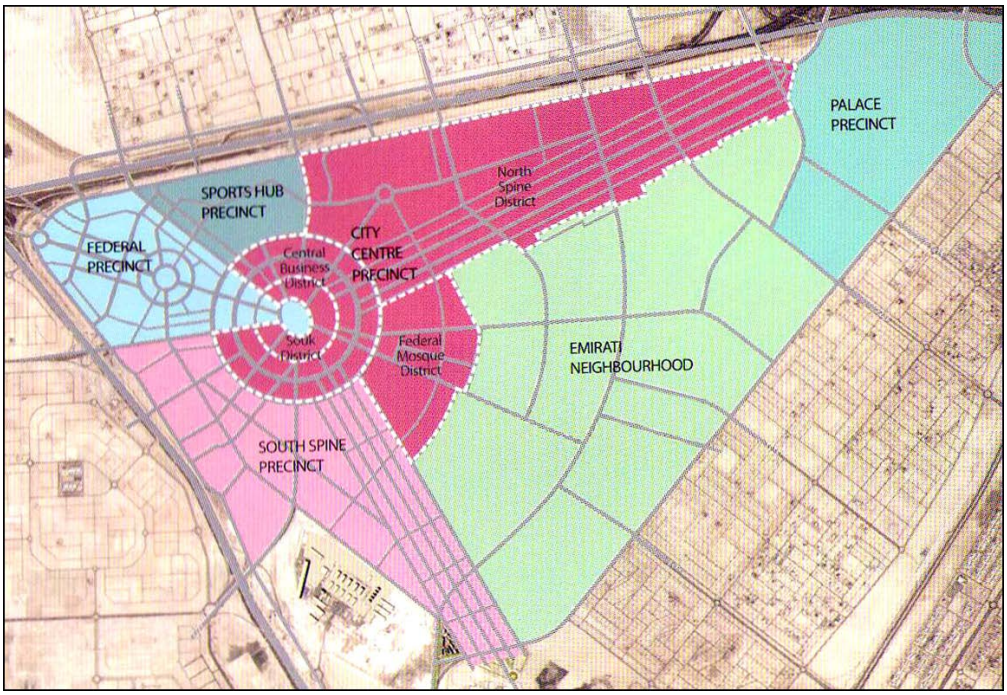

Fig. 2 The six major precincts of the Capital District
Source: ABU DHABI URBAN PLANNING COUNCIL. *Plan Abu Dhabi 2030- Urban Structure Framework Plan*, Abu Dhabi, UAE, 2007

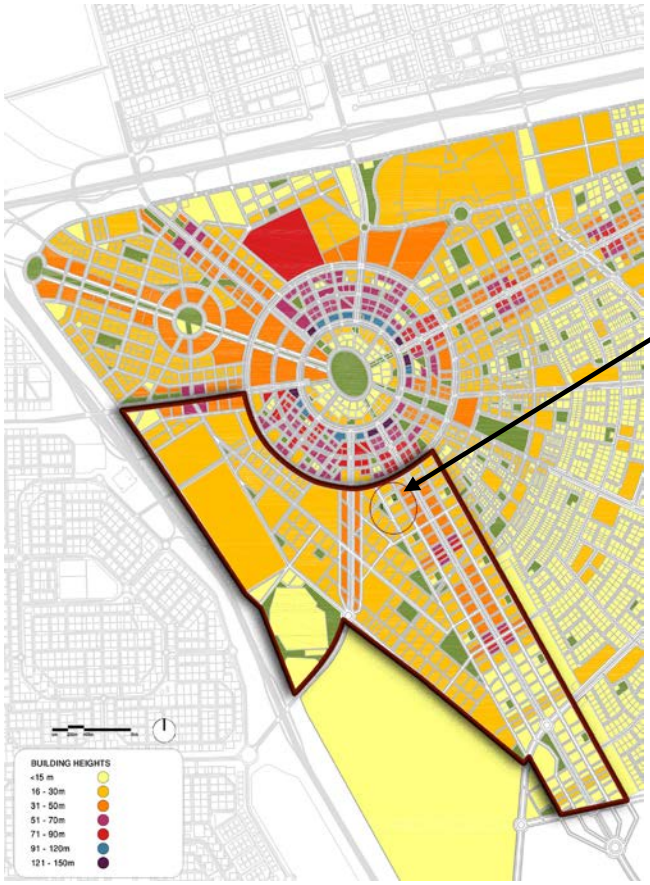

Fig. 3 (a) The building height map of south spine showing the location of the selected sites
Source: ABU DHABI URBAN PLANNING COUNCIL. *Plan Abu Dhabi 2030- Urban Structure Framework Plan*, Abu Dhabi, UAE, 2007

Fig. 3 (b) The selected sites and their surrounding plots

IV. METHODOLOGY

According to the above criteria two models were proposed as scenarios for shadow simulation by using the SketchUp 3D program. The study is designed to assess the effectiveness of building arrangements and analyse different proposals to study their effect on microclimate, in particular decreasing the temperature through the creation of shadow.

Shading by using landscape and special pavement materials was not taken into consideration, nor was the humidification or ventilation of the spaces. This research focuses only on one aspect: shading by building arrangement, including building form and height. Because the same building arrangements will be tested to check the visibility of the same open spaces in another research the visibility of the open spaces A and B was considered as much as possible. Hence the research aims to propose the most suitable building arrangement that produces the maximum amount of shadow and offers the maximum visibility of open spaces A and B.

It is important to note here that other factors affecting the microclimate were not neglected, but we preferred in this research to follow a different approach, using simple computer programs that can be used at different levels of competency, not only by professionals. At the end this research provides a model that can be followed by students in their proposals. The major objective of this paper is to pay attention to two aspects: visibility to open spaces and amelioration of the microclimate by shading outdoor spaces.

It is necessary to mention that a balance has to be made between minimizing the buildings exposure to the sun to minimize the increase of temperature inside the building skin and its interior spaces, and between using the building to shade such outdoor spaces as walkways and parks. While many research papers have focused on cooling techniques and strategies applied to buildings, and also include study of suitable orientations, materials, etc. less research has given importance to strategies to produce a comfortable microclimate in the outdoor spaces and open areas.

It is true that most buildings will be occupied for a greater time and by more people than the open spaces, but in my opinion, buildings can still be cooled more by passive and active techniques than the open spaces. While air conditioning can be used in extreme situations indoors, its use in large open spaces is virtually impossible, yet the use of air conditioning increases the energy consumption and costs. But here a balance has to be made between the financial versus social aspects requiring us to reconsider our choices and decisions concerning the natural and built environment, in particular between buildings and open spaces.

V. BUILDING ARRANGEMENTS

Fig. 4 shows the possible arrangements that were applied to the study area and verified by using the criteria mentioned earlier: the distances between buildings, the size of the plots, the visibility of the open spaces A and B, providing a small open space for the community in case of any residential or mixed use of the plot. The application of the linear arrangement in a horizontal, vertical and oblique ways, the U-shape arrangement, the L-shape arrangement and the combination between the L-shape and linear arrangements were checked. Finally only two designs based on the Scenario 1 “Linear” shape (Fig. 5.) and the Scenario 2 “L” shape (Fig. 6.) were verified as suitable to represent the simulation scenarios.

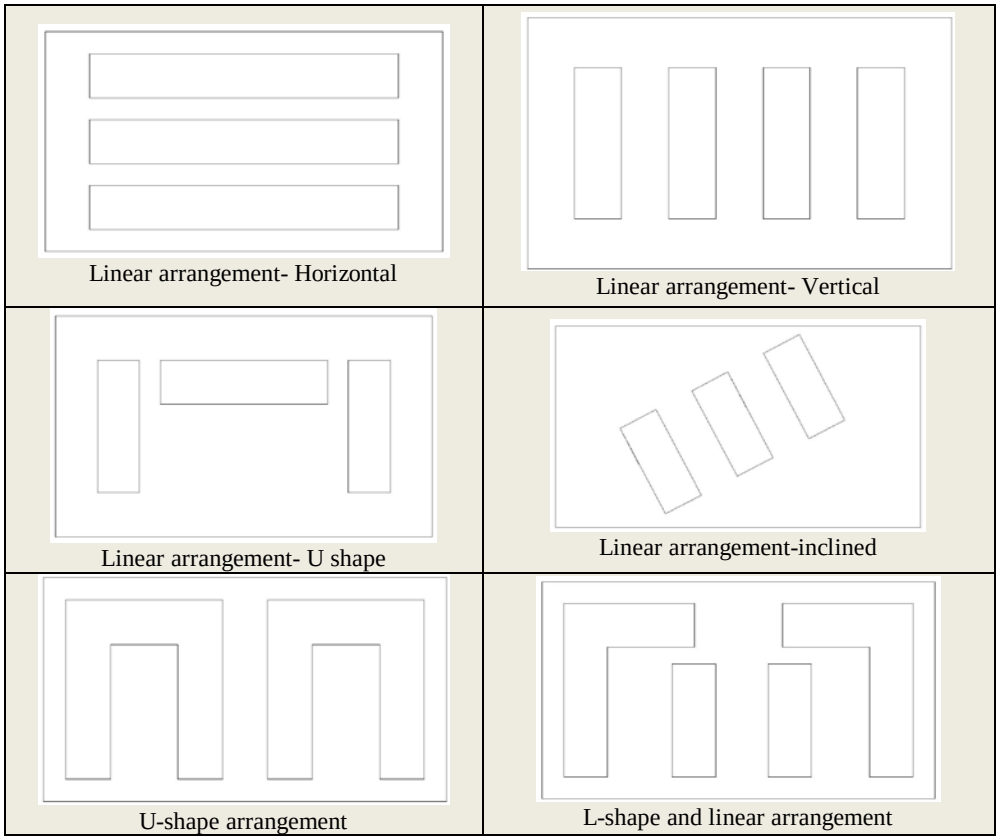

Fig. 4 Possible building arrangements that were studied

VI. Simulation

To Study the climatic and the shadow on our selected sites we carried out two scenarios taking in to account the minimum and maximum height allowed for each plot according to the Abu Dhabi Master Plan 2030 (Fig. 3.a) and the views to open spaces in order to combine the results with the other simulations undertaken in other research to study the visibility of the open spaces.

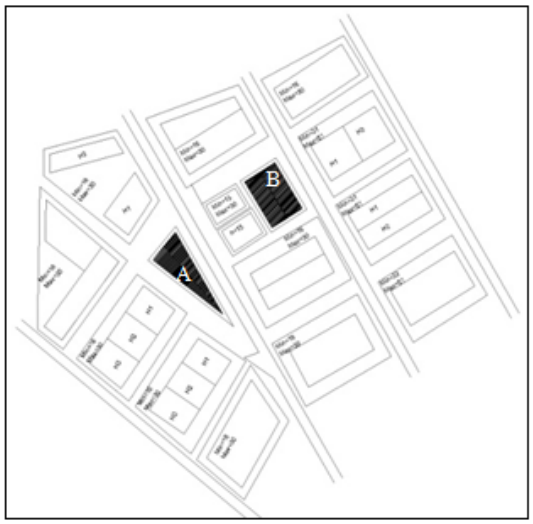

Fig. 5 Scenario 1

Days were chosen in relation to the hottest days of the year and using different timings on the peak days in summer and winter as follows: Summer on 21 June and winter on 21 December at 6.30am, 10.30am, 1.30pm, 3.30pm and 5.30pm and 6.30pm. Fig.7, 8, 9, and 10 show simulations of scenarios 1 and 2 considering the minimum and maximum heights.

The area of the shaded areas from open spaces A and B was measured as a percentage and then the average was calculated for each simulation day (Fig. 10, 11, 12 and 13.).

Fig. 6 Scenario 2

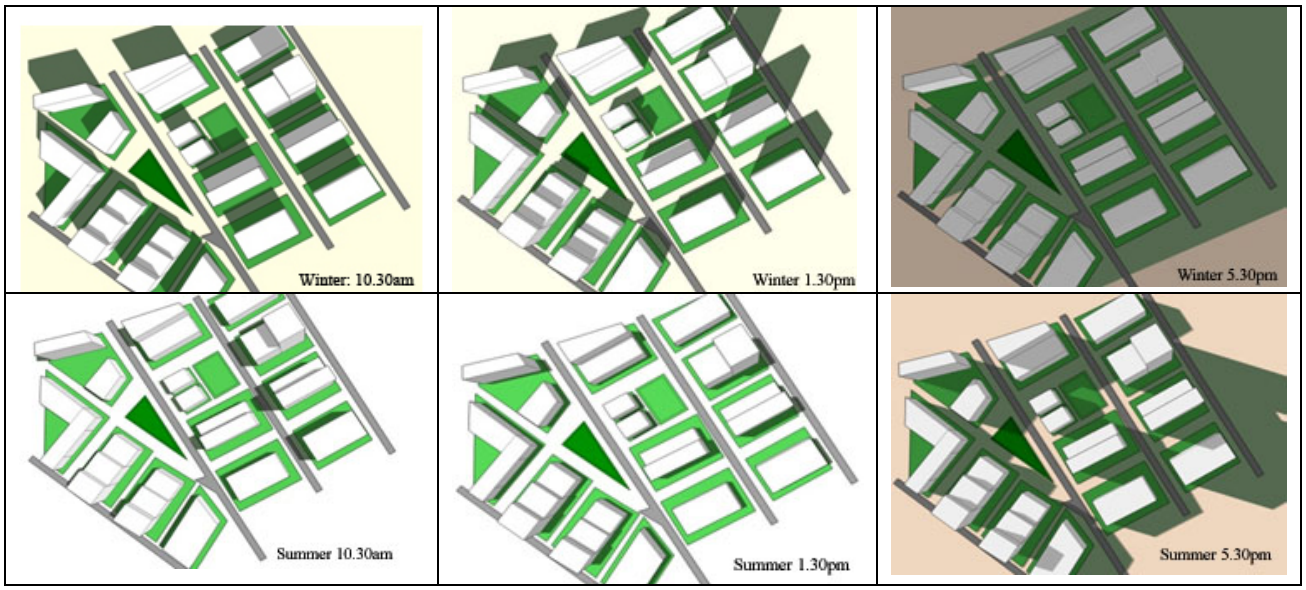

Fig. 7 Scenario 1: minimum height

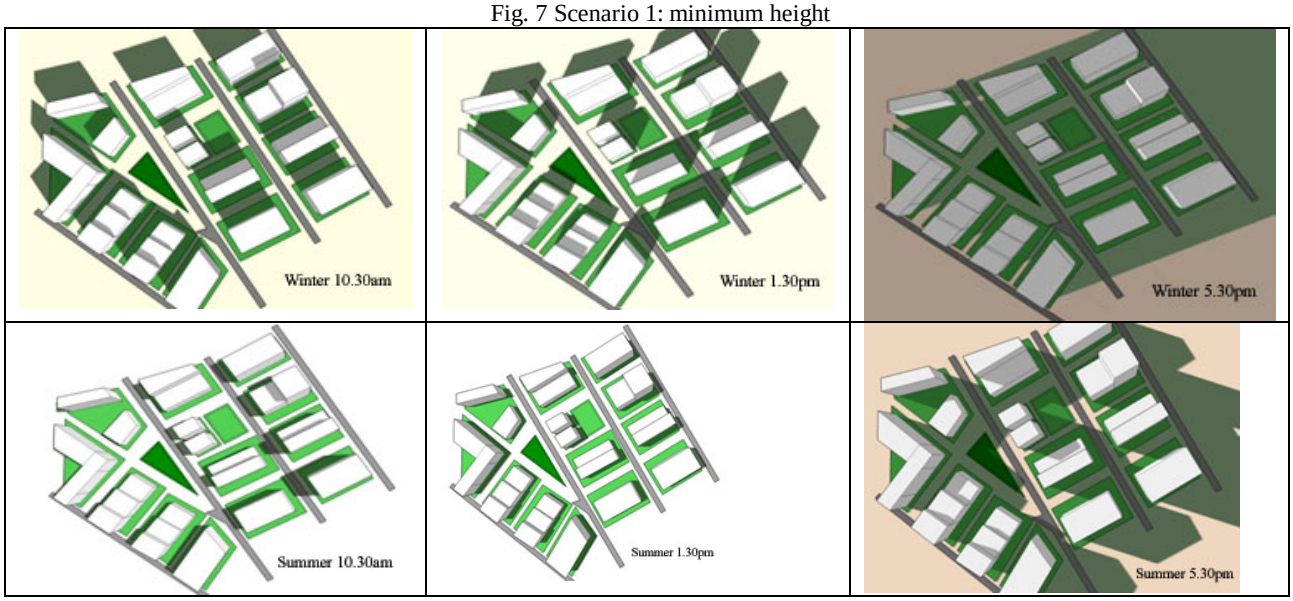

Fig. 8 Scenario 1: maximum height

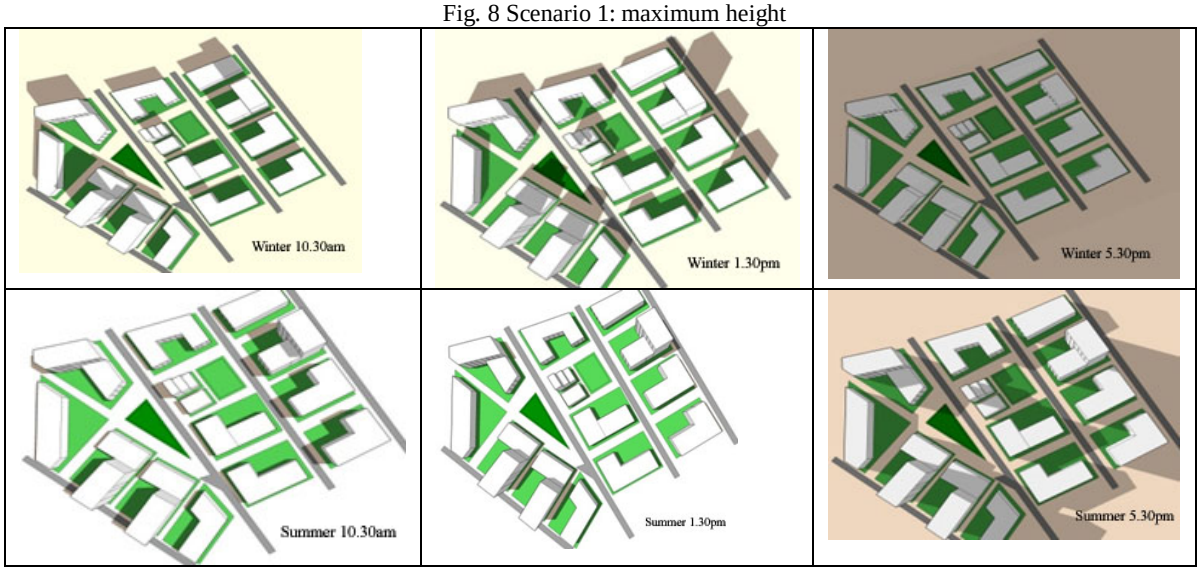

Fig. 9 Scenario 2: minimum height

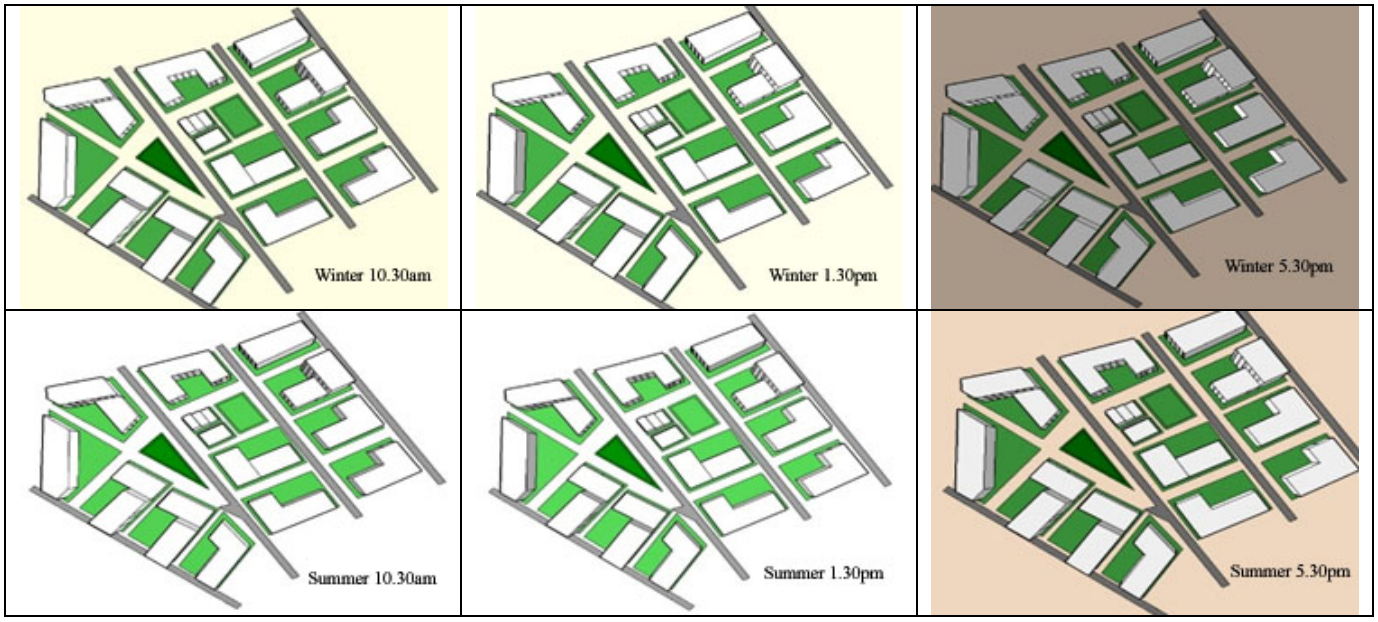

Fig. 10 Scenario 2: maximum height

VI. RESULTS ANALYSIS AND FINDINGS

After calculating the average of the shaded areas as a percentage (Fig. 10, 11, 12, and 12), we compared the results and found that the maximum height gives better results in shading more areas in summer, however the second scenario gives more shadow at 5.30pm. So, we suggest applying the second scenario which is based on the L-shape arrangement of buildings. The reason being that by 5.30pm at the end of the afternoon, one of the simulation times, the sunshine is not as intense and many people are free after work or study to use the outdoor areas more than in the morning at 10.30am, when children are at school, and parents working. At the peak of the day from 12.00pm to 3.30pm the temperature is very high.

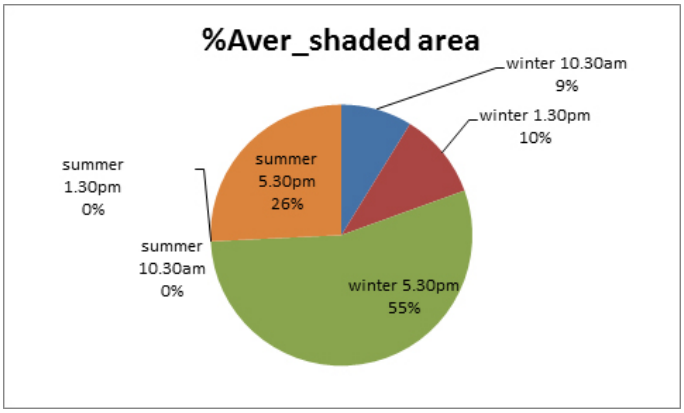

Fig. 11 Simulation results of Scenario 1 -Minimum height

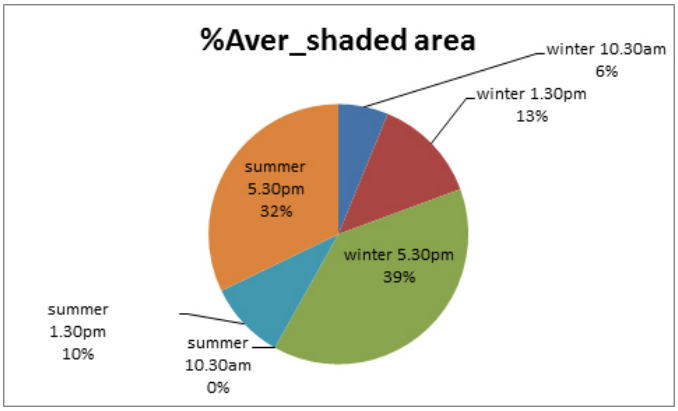

Fig. 12 Simulation results of Scenario 1 -Maximum height

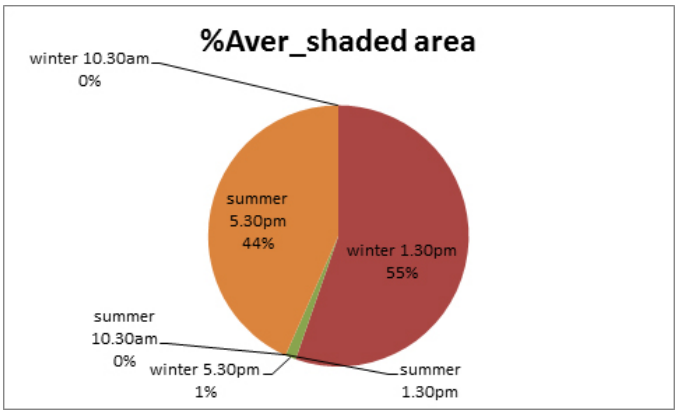

Fig. 13 Simulation results of Scenario 2 -Minimum height

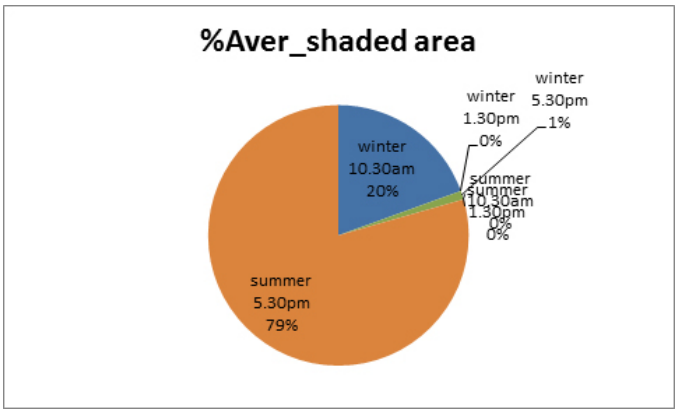

Fig. 14 Simulation results of Scenario 2 -Maximum height

VII. CONCLUSION

The study determined that buildings designed to the maximum allowable height will provide a greater amount of shading during summer and winter.

Since the climatic problem in the UAE is the intense heat in summer, and because Scenario 2 with its maximum building height gives the maximum of shaded spaces in summer, we suggest using Scenario 2 with its L shape as a building form. This building arrangement would also be suitable for residential land use to produce small open spaces for the community.

We took the scenario that gave us a more shaded area in summer, when the heat is a real problem. People would definitely not use outdoor spaces in July and August when temperatures reach 45C and above, but at least they could benefit in June (the month of simulation).

ACKNOWLEDGMENT

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REFERENCES

[1] ABU DHABI URBAN PLANNING COUNCIL: Plan Abu Dhabi 2030-Urban Structure Framework Plan, Abu Dhabi, UAE, 2007.
[2] ABU DHABI URBAN PLANNING COUNCIL: Capital District. Abu Dhabi 2030 Vision, Abu Dhabi, UAE, 2007.
[3] ALAN PENN: Space Syntax and Spatial Cognition- or, Why the Axial line? 3rd International Space Syntax Symposium, Atlanta, USA, 2001.
[4] AYSE KUBAT, Samia Rab,Yasmin Ince Guney,Ozlem Ozer, Serdar Kaya: Application of Space Syntax in Developing A Regeneration Framework for Sharjah's Heritage Area. 8th International Space Syntax Symposium, Santiago De Chile, 2012.
[5] BILL HILLIER: The Art of Place and the Science of Space. In "World Architecture", Special Issue on Space Syntax, pp.96-102, Beijing, 2005.
[6] JAKE DESYLLAS, Elspeth Duxbury: Axial Maps and Visibility Graph Analysis. A Comparison of their methodology and Use in models of Urban Pedestrian Movement. 3rd International Space Syntax Symposium, Atlanta, USA, 2001.
[7] RIM MEZIANI, Toshiyuki Kaneda: Toward Further Application of Visibility Analysis in the Case of Ghardaia. 10th International Conference on: Computers in Urban Planning and Urban Management (CUPUM), Iguassu falls, Brazil, 2007.
[8] TURNER ALASDAIR: Depthmap: A Researcher's Handbook. Bartlett School of Graduate Studies, UCL, London, 2004.
[9] TURNER ALASDAIR: Angular Analysis. 3rd International Space Syntax Symposium, Atlanta, USA, 2001.
[10] Wikipedia
[11] http://geography.about.com/library/cia/blcuae.htm