Military Technical College
Kobry El-Kobbah,
Cairo, Egypt

9th International Conference on
Civil and Architecture Engineering
ICCAE-9, May2012

Climate Based Design Decision Support for Urban Village Development: A case study in Nuba, Egypt

Hany Mokhtar*, Mohammad Fahmy* and Amr Gira*

Abstract

Upper Egypt region is characterised with harsh hot arid climate conditions which means that even mechanical cooling cannot be applied on a wide scale of urban housing projects. Therefore, urban passive desig n principles should be considered in present climate conditions to conclude an acceptable indoor human thermal comfort conditions and crucially for future conditions. As part of NUBA urban villages' development project, NUBA, sponsored by the Egyptian Gov ernment, this paper investigates the mean outdoor thermal comfort of two urban housing alternatives. The case study is a new development to the west of Aswan International Airport and consists of eight urban villages each of which is composed of a group of clusters accommodating about 2000 people. First alternative has been almost approved for construction on a rush of time for as a fast replacement for Nuba people old houses due to the new urban planning of Aswan; it has been designed without full consider ation for passive techniques nor for the Egyptian Energy Code in Residential Buildings. That is why the second alternative tries to support redesign of the rest villages. Numerical simulations took place to generate outdoor meteorology for present day and the year 2050. Results of whole village outdoor spaces showed that second alternative is far better than the first both in present day and in future, proofed that there is no choice but to design passively in such hot arid region and proofed the passive d esign methodology used.

Key words: passive design, climate change, air temperature

1. Introduction:

1.1 Climate based urban planning

Urban developments have short run cost, and long run cost as well. From a thermal performance point of view it consid ers human thermal comfort, energy consumption and climate change [1-3]. Climate based urban planning is a multidisciplinary interacted group of fields such as Meteorology, human biometeorology, architecture, urban planning, urban design, landscape and landscape architecture, physics, human physiology, remote sensing ….etc [4, 5].

* Department of Architecture, Military Technical College, Cairo, Egypt

To start work in an urban planning and development case, urban planner and designer should define its corresponding climate scale, have a basic knowledge of urban thermal interactions and urban passive tools and have to know what urban passive system is [6]. Up to about 1km2 is corresponding to local climate scale which in turn is corresponding to a neighbourhood/village site area [7]. The bigger the scale of urban site and in turn its climate scale, the more complexity of designing urban form is [8, 9]. Built environment has three physical elements affecting its thermal performance and in turn all related sustainability issues, these are fabric, network and vegetation [7, 10-13]. Urban street canyon thermal studies have been presented by many researches [14-17], for only single cross section which doesn't represent a whole neighbourhood/village thermal performance when assessing different alternatives. As cities are considered agents for regional/global climate [18], neighbourhoods/village are considered the agents for cities climate [6] as they are the urban planning units for them [19]. For that purpose, Fahmy [20] presented an averaging methodology for meteorological parameters of all local scale urban spaces to represent whole neighbourhood/village. Consequently, urban form alternatives can be objectively assessed in present and future on a climate basis as well as on other urban design appraisal methods [21-23] to support decision making. Future conditions refers to climate change scenarios reported by the Intergovernmental Panel for Climate Change [24], which are generated for the years 2020, 2050 and 2080 either by morphing or stochastic methods [25, 26]. It is argued that major climate change effects in Egypt will be air temperature increase as well as a recess in the Nile delta due sea level rise of about 20-60cm which means temperature increase, thermal sensation and comfort levels. Therefore, urban developments should account not only for present day conditions, but also for future ones.

1.2 Urban development in Aswan

Upper Egypt urban development major projects started about 20 years ago by coupling the east river Nile cities with new parts at the river west bank. One governorate of this Egyptian region, Aswan, (N 23° 58'- E 32° 46'), has an international reputation for its cultural heritage and the open historical built environment showing the monumental development that ancient Egypt had. For this reason and to protect such treasures along with the hidden ones under Nuba old villages' houses, a massive urban development project has been launched for southern part of Aswan, the Nuba, and had the fund and political support. Nuba is the region starts around Lack Nasser and continues into the lands of Suddan, its people has their deep history in contact with ancient Egypt, and their villages can be distinguished through the works of the late famous Architect Hassan FatHy [27]. As part of NUBA urban development project, relocating some old villages has been decided to consider them antiquities protectorates due to the many discoveries found under houses. NUBA has the role of designing a community of eight urban villages to the west of Aswan International Airport of about 15km. Such conditions guided the vernacular Nuba urban villages towards compact forms with narrow streets, mud walls and thermal masses along with light colors and courtyard housing. The average population density of Nuba villages is …..p/feddan [28].

1.3 Case study

The site is located in Karkar Nubian area about 10km to the west from Aswan International Airport, fig.1. With area of about 494 feddans (feddan is about 4200m2), and divided into eight villages planned to accommodate about 20000 people of about 2000 for each village, urban planning was radically guided from the government after geotechnical, social and economical studies but with minor consideration for climate.

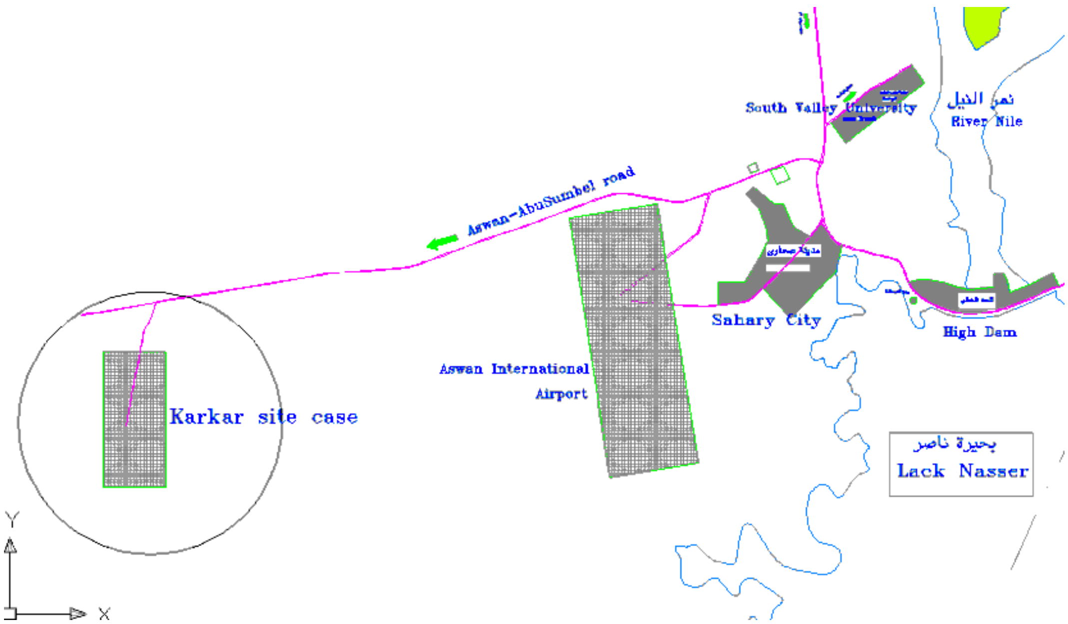


Figure (1): Nuba region map indicating Karkar site in relation to Aswan city of which the High Dam lays at the centre.

This appeared in the concrete skeleton construction of the service buildings and absence of passive design techniques, fig.2, regardless the vernacular form of fabric. Based on 30 years of WMO Station no. 624140, the region is classified as Subtropical hot desert characterized with harsh conditions of unbearably hot dry periods in summer, but passive cooling is possible [29, 30]. With less than 20% of relative humidity and 8770 Wh/m² of global radiation, its extreme hot week period lays between Jun 29th: Jul 5th, maximum air temperature of 47.5°C, whereas the typical week period between Jun 8th: Jun 14th, average air temperature of 34.1°C. The extreme summer hot day is the 1st of July, fig. 3, as analyzed by ECOTECT2010 [31].

Figure (2/a, b): Design sets illustrations for; 1 to the left and 2 is right.

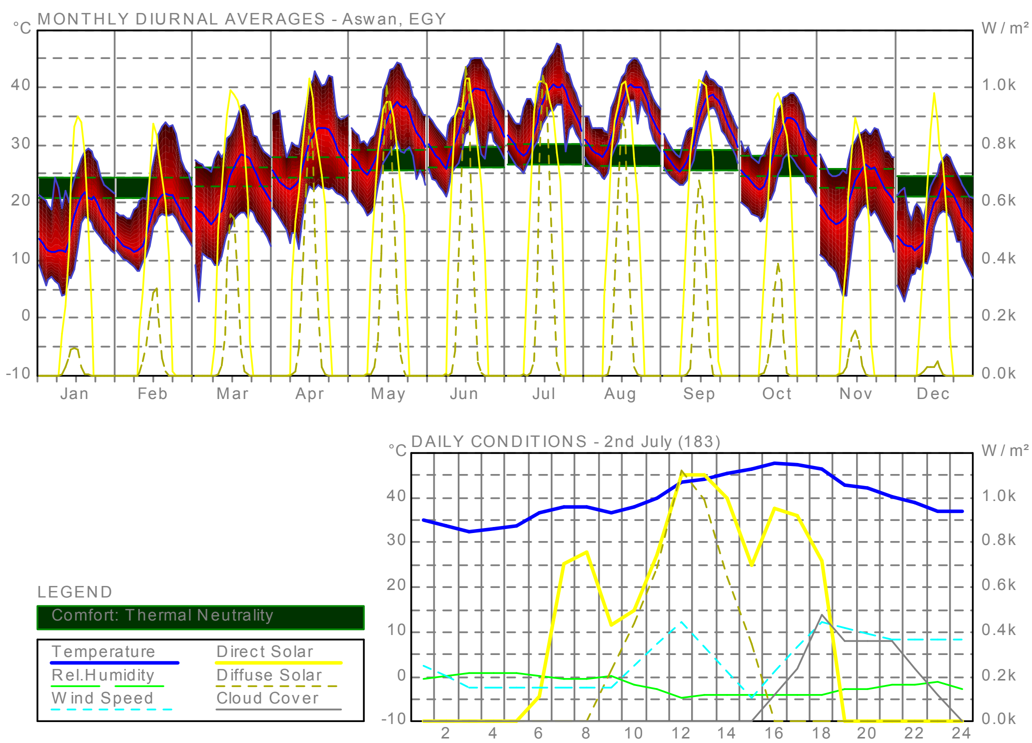


Figure (3): Meteorological measurements at WMO weather station no. 624140 of Aswan corresponding to the extreme hot summer day analyzed by ECOTECT 2010.

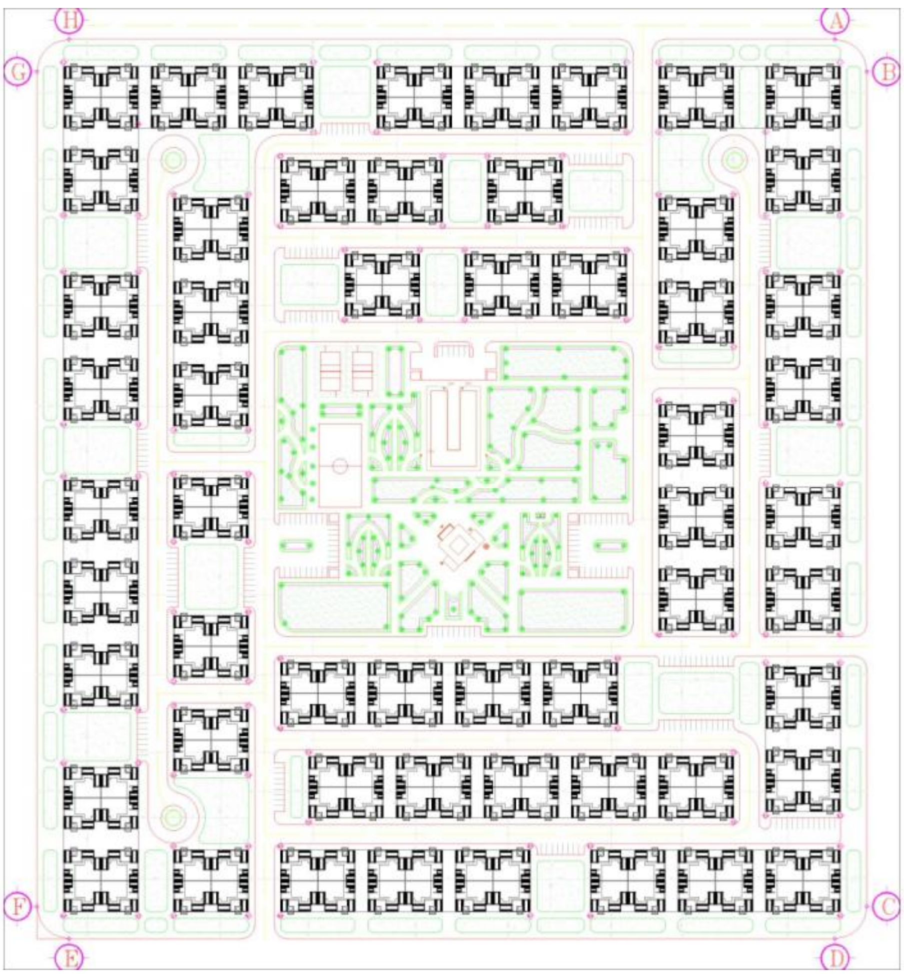
Table 1 shows urban planning statistics for the already approved proposal for one of the villages in comparison with the newly suggested proposal.

Table (1): Housing design and land use statistics;

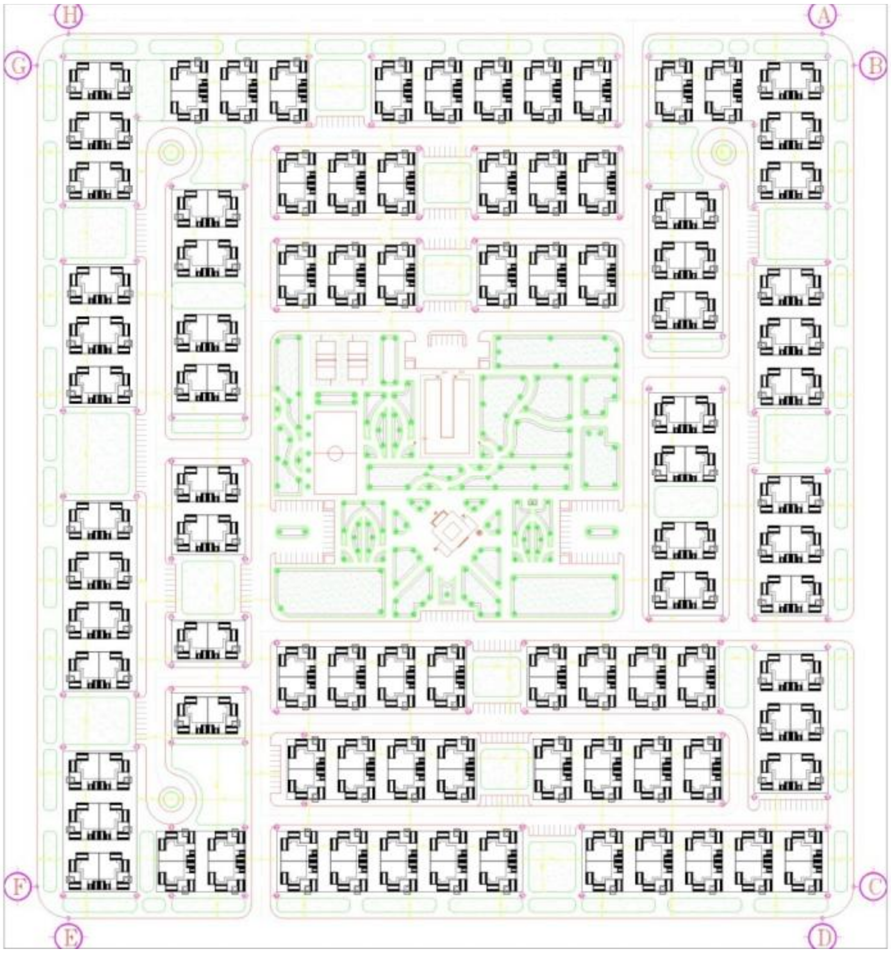
	Name of design alternative	Urban site total area in feddans	Green coverage percentage	Total urban construction percentage	Max. No. of families	Total population	Population /feddans
1	Base Case		18.5 %	17.4 %	224	896	23.02
2	proposal 1	38.92	18.0 %	14.8 %	180	720	18.5
3	proposal 2		18.0 %	14.8 %	360	1440	37

- Feddan = 4200m^2.

The main difference in the urban form of the first alternative is the fabric orientation in addition to separating the four housing units from being clustered around single courtyard. second alternative applies more dense housing using two floors instead of one and less court exposed area which means more compactness degree and hence an expected better thermal performance [6], fig. 4, Show the urban design for the base case and the proposal, Fig. Show5 indicates a 3D visualization for the two alternatives.

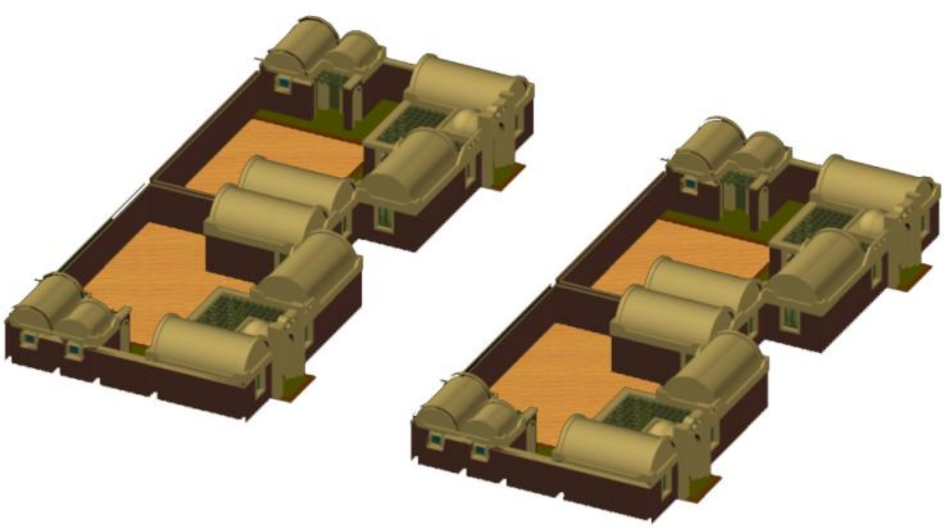


(4/a)



(4/b)

Figure (4/a, b): Show the urban design for the base case and the proposal



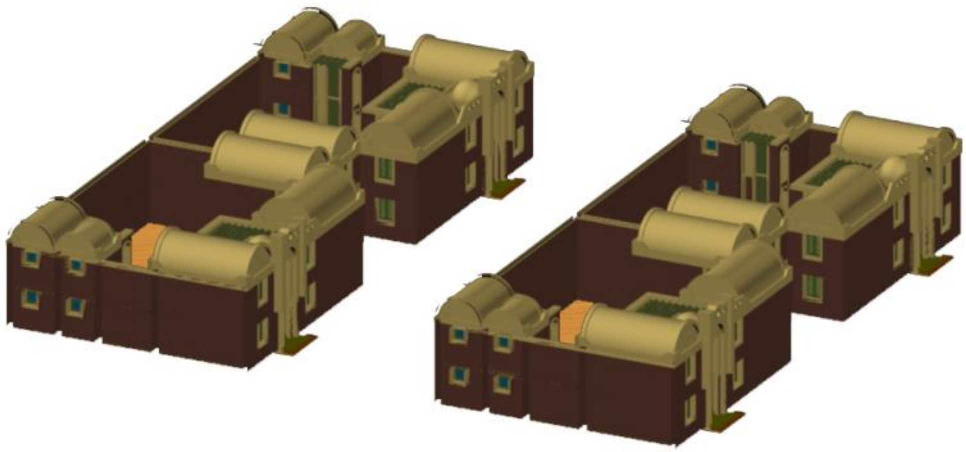


Figure (5/a, b): 3D visualization for the two alternatives.

2. Methodology

In order to support the design decision by giving an advantage for one of the proposals, an assessment for the whole urban form design outdoor and indoor thermal performance took place as both of them are important for accreditation of one of them than another. The conductive heat relation between outdoor and indoor climate conditions consequates particular indoor thermal comfort levels which in turn defines other sustainability measures such as energy demand and carbon emissions. Simulation was the preferred method due to the large area of the case study as well as the non - representation for the whole site if measurements took place at selected points. Most of thermal performance simulations tools use files of the open horizon meteorological data measured at a distance from urban, therefore, an outdoor conditions' parameter ha d to be investigated as well as its corresponding indoors to refer to specific urban form details rather than the open horizon. From these standing points, air temperature is averaged at 1.2m above ground level for 12h to represent outdoor environment the rmal performance through the numerical simulation model ENVI -met BETA5 on the 1st of July as an extreme summer hot day in Aswan. ENVI -met is a CFD microclimatic model which is capable of simulating the built environment surface -air-plant thermal interactions based on the fluid dynamics and heat transfer fundamentals, solar movement and vegetation databases and it proofed reliable usage in the scope of environmental impact assessment [35]. The later study concluded that a complete vision about urban development thermal performance should couple both outdoor and indoor investigations as urban spaces affect the indoor comfort and energy consumption. Moreover, climate change weather scenarios were generated using CCWorldWeatherGen [37] to predict outdoor air temperature levels for base case and the modified proposals at the year 2050 which is the urban develop ment projects' targeted year in Egypt. CCWorldWeatherGen uses present day weather data file compiled in an Energy Plus file with ETMY format [29] to generate new file for the targeted year; 2050. This means that each proposal had two outdoor assessments for present day and future, and hence the total simulations are 6 each of them took about 5 days to simulate 9h of the selected day. To ease writing the names of proposals, base case will be named BC, the 1st proposal will be P1 and the 2nd proposal is P2. For present day simulations abbreviation is PD and for climate change scenario simulation called CC. So the 2nd proposal in future can be named as P2CC.

3. Results and analysis

The trend of air temperature curves for the four master plans simulations (BCPD, P1PD, BCCC and P1CC) are the same, increasing at noon and start to decrease by evening, fig. 6. The extreme temperature degree for the BCPD was 32.8 C° at 12:00pm and for P1PD was 33.8 C° at 2:00 pm. At 8:00 am the temperature for the base case was 28.7 C° where the proposal case was 25.7 C° but at 4:00 am the temperature for the base case was 29.0 C° where the proposal case was 33.8 C°.

It is then clear that P1 air temperature results was less than its BC corresponding till 12:00 pm but after that it started to increase than BC. Since the fabric building materials are the same, it can be argued that the more open sky view factor (SVF) of P1PD contributed to more gain of direct solar radiation. SVF of BCPD was 0.86 whereas for P1PD was 0.87 in turn the shaded area of BCPD was more than P1PD. Consequently, there are two options to achieve more shaded area and less SVF. Either to increase vegetation compared with BCPD or to increase the building -street aspect ratio H/W to generate more shade.

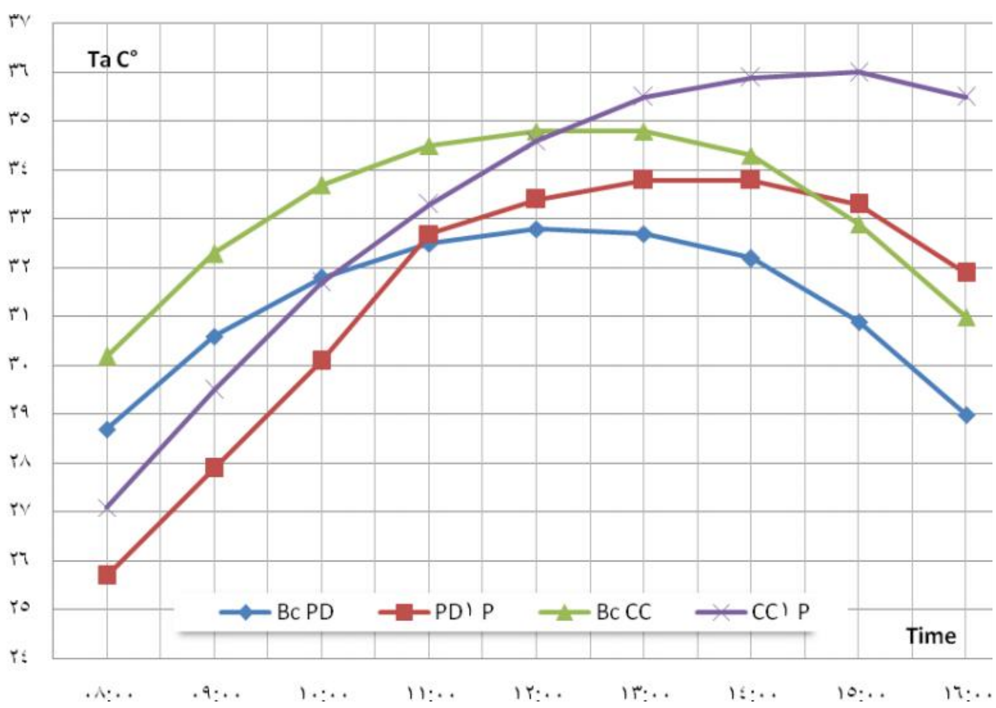


Figure (6): Air temperature curves for the four master plans simulations

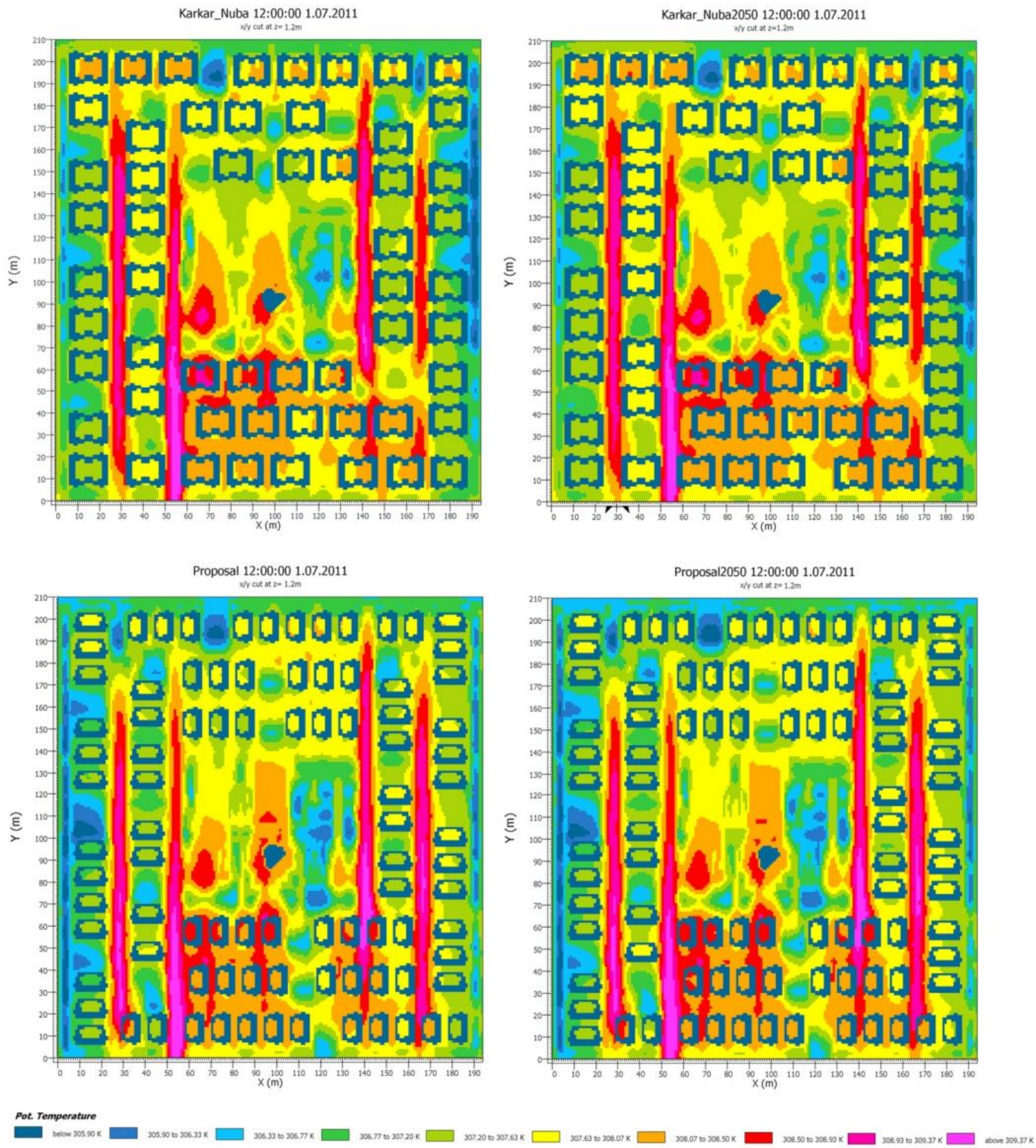


Figure (7): T_a mapping for BCPD, P1PD, BCCC and P1CC respectively, at 12.00 LST.

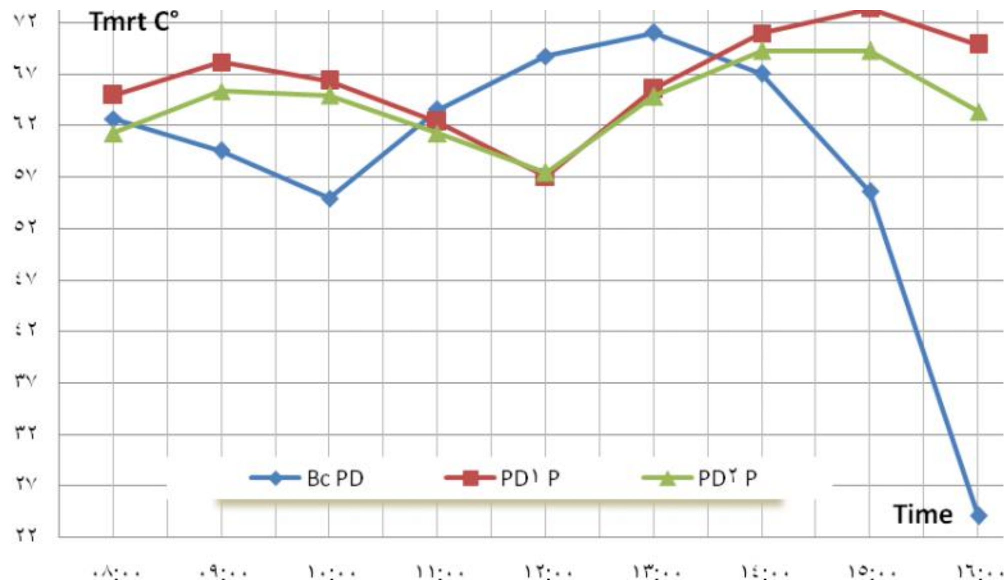


Figure (8): Radiant temperature curves for the base case and the two proposals

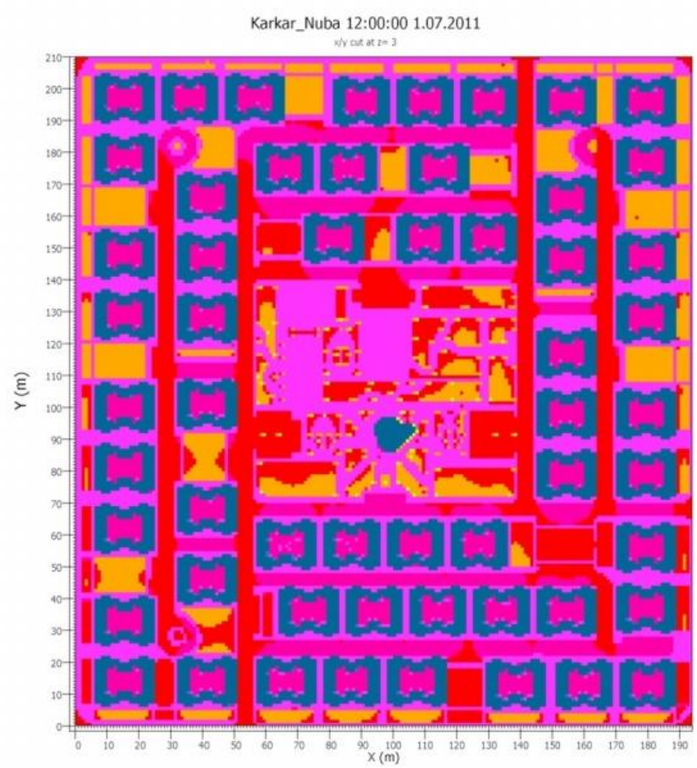


Figure (9): Tmrt mapping for BCPD, P1PD and P2PD respectively, at 12.00 LST.

4. Conclusions:

This paper discussed the microclimatic effects of an urban village form in Karkar, Nuba. The already existing form hasn't considered passive design strategies; therefore, this work suggests another two urban forms as if passive strategies have been considered. The two proposals were designed on the same land use without changing fabric morphology or housing typology. So, the only way to increase urban compactness of the village was to increase the heights to conclude more shading. By increasing the compactness using more floors, both proposed urban village forms showed more comfortable outdoor spaces at peak time. Despite this happened, the base case showed more comfortable urban spaces before and after peak time (11:00 – 14:00LST). It can be argued that introducing passive strategies in the late design stages as presented in the work didn't affect whole the day time comfort. From this standing point, such approaches of passively designed physical form weather urban or not, should be embedded in the design process to show more control on the built environment climate by controlling the land use and the fabric morphology them selves.

5. References:

[١] Fahmy M, Sharples S. Urban form, thermal comfort and building CO_2 emissions – a numerical analysis in Cairo. . Building Services Engineering Research and Technology 2011a(1):1-12.

[٢] Levermore GJ. A review of the IPCC Assessment Report Four, Part 2 : Mitigation options for residential and commercial buildings. Building Service Engineering 2008;29(4):363-74.

[٣] McEvoy D. Climate Change and Cities. Built Environment 2007;33(1):5-9.

[٤] Ali-Toudert F. Dependence of Out Door Thermal Comfort on the Street Design in Hot and Dry Climate. PhD. Thesis, Freiburg, Germany: Institute of Meteorology; 2005.

[٥] Fahmy M. Interactive urban form design of local climate scale in hot semi -arid zone. School of Architecture. Sheffield: University of Sheffield; 2010.

[٦] Fahmy M, Sharples S. On the development of an urban passive thermal comfort system in Cairo, Egypt. Building and Environment 2009a;44(9):1907-16.

[٧] Oke TR. Boundary layer climates. London: Methuen; 1987.

[٨] Eliasson I. The use of climate knowledge in urban planning. Landscape and urban planning 2000;48(1-2):31-44.

[٩] Oke TR. Towards better scientific communication in urban climate. Theoretical and Applied Climatology 2006;84(1-3):179-90.

[١٠] Akbari H. Shade trees reduce building energy use and CO_2 emissions from power plants. Environmental Pollution 2002;116(1):S119-S26

[١١] Rahamimoff A. Residential Cluster Based on Climate and Energy Considerations. Energy and Buildings 1984;7(2):89 - 107.

[١٢] Rosenfeld AH, Akbari H, Bretz S, Fishman BL, Kurn DM ،Sailor D, Taha H. Mitigation of urban heat islands: materials, utility programs, updates. Energy and Buildings 1995;22(3):255-65.

[١٣] Dimoudi A, Nikolopoulou M. Vegetation in the Urban Environments: Microclimatic Analysis and Benefits. Energy and Buildings 2003;35(1):69-76.

[١٤] Ali-Toudert F, Mayer H. Numerical study on the effects of aspect ratio and orientation of an urban street canyon on outdoor thermal comfort in hot and dry climate. Building and Environment 2006;41(2):94-108.
[١٥] Ali-Toudert F ،Mayer H. Thermal comfort in an east-west oriented street canyon in Freiburg (Germany) under hot summer conditions. Theoretical and Applied Climatology 2007a;87(1-4):223-37.
[١٦] Oke TR. Street Design and Urban Canopy Layer Climate. Energy and Buildings 1.١٣-١٠٣:(٣-١)١١؛٩٨٨
[١٧] Pearlmutter D, Berliner P, Shaviv E. Physical modeling of pedestrian energy exchange within the urban canopy. Building and Environment 2006;41(6):783-95.
[١٨] Gerald M. Cities as agents of global change. International Journal of Climatology 2007;27(14):1849-57.
[١٩] Allam A, Geith M. Planning The Neigbourhood, in Arabic. Cairo: Madbouly Book Shop Publishers; 1995.
[٢٠] Fahmy M. As if climate mattered I: Passive solar neighbourhood planning in Cairo, Egypt. Submitted to Renewable Energy 2011c.
[٢١] Shirvani H. The Urban Design Process. Book, Van Nostrand Reinhold Company, NewYork 1985
[٢٢] Moughtin C, Cuesta, R., Sarris, C., Signoretta, P. Urban Design: Method and Technologies. London: Architectural Press; 2000.
[٢٣] Moughtin C. Urban Design: Street and Square. Oxford: Butterworth Architecture; 1992.
[٢٤] IPCC. HadCM3 climate scenario data download page, www.ipcc-data.org/sres/hadcm3_download.html. 2010.
[٢٥] Belcher SE, Hacker JN, Powell DS. Constructing design weather data for future climates. Building Service Engineering 2005;26(1):49-61.
[٢٦] Jentsch MF, Bahaj AS, James PAB. Climate change future proofing of buildings--Generation and assessment of building simulation weather files. Energy and Buildings 2008;40(12):2148-68.
[٢٧] FatHy H. Architecture for the Poor: An Experiment in Rural Egypt. chicago; 1973.
[٢٨] CAPMAS. Final Report of Population Statistics for Egypt 2006. Cairo: Central Agency for Public Mobilisation and Statistics; 2008.
[٢٩] DOE. Egypt weather data [Online ،[Available:http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data3.cfm. Accessed 18/7/2009.; 2009.
[٣٠] ASHRAE. ASHRAE Hand Book of Fundamentals (SI Edition). Atlanta: American Society of Heating, refrigerating, and Air-Conditioning Engineers Inc.; 2005.
[٣١] AutoDesk. ECOTECT2010, [Online], Available at: http://www.autodesk.co.uk/adsk/servlet/mform?validate=no&siteID=452932&id=14205163. Accessed 19/4/2010.; 2010.
[٣٢] HBRC. Energy Efficiency Residential Building Draft Code (EERBC) for New Residentail Buildings, Additions and Retrofits. Cairo: Egyptian Ministry of Housing, Utilities and urban Communities; Housing and Building Research Centre.; 2010.
[٣٣] Jendritzky G, Nübler W. A model analysing the urban thermal environment in physiologically significant terms. Meteorology and Atmospheric Physics 1981;29(4):313-26.

[٣٤] Jendritzky G, Sönning W, Swantes HJ, Beiträge d, Akad f. Ein objektives Bewertungsverfahren zur Beschreibung des thermischen Milieus in der Stadt - und Landschaftsplanung) Klima-Michel-Modell). Raumforschung und Landesplanung 1979;28.
[٣٥] Fahmy M, Hathway A, Pattacini L, Elwan A. Environmental thermal impact assessment of regenerated urban form: A case study in Sheffield. Wroled Renewbale Energy Congress. Sweden.; 2011b.
[٣٦] Fahmy M, Trabolsi A, Sharples S. Dual stage simulations to study microclimate thermal effect on comfort levels in a multi family residential building . 11th International Building Performance Simulation Association Conference Universit y of Strathclyde in Glasgow, 27-30 July; 2009.
[٣٧] CCWorldWeatherGen. Climate Change World Weather File Generator. SouthHampton: School of Civil Engineerign and the Environment ; 2010.