Once upon a climate: arid urban utopia of passive cooling and the diversity of sustainable forms

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As sustainability is needed for built environment future, reducing communities' energy consumption and passive design are the only choices. Such approaches will also deliver improved urban thermal comfort for urban spaces. It has been argued that the complexities of urban climatology prevented the connection between climate knowledge and urban planning practice. Examples drawn for quarter neighbourhood design sets in Cairo were investigated using the numerical environmental modelling package (Envi-Met), explored the role urban passive planning can have in generating urban diversity as an important measure for urban sustainable forms. Urban form diversity can be presented in three factors. First, the degree of diversity, Dv; it is the ratio of whole site facades' areas to the whole urban site area. Second is urban context and third is housing typologies. A Degree of site compactness Dc, is the average urban site height multiplied by the urban constructed area. By increasing details of the clustered form used, simulations indicated a direct proportional relation between Dv and Dc. Maximum Dc of 2nd design set showed the highest Dv value of 2.25 and reported better comfort levels. But, this form height achieved by population limit of Egyptian urban planning law could be more than the allowed 1.5 aspect ratio value of street canyon. Consequently, the less Dv of 2nd design set was preferable. Results conducted that, whilst the detailed form is concluded by urban passive utopia search for cooling in hot regions, the comfort provision not only helps form thermal sustainability but also its urban diversity.

Keywords: Degree of compactness; Dc, medium population form, sustainable development, urban comfort, Degree of diversity; Dv

1 Introduction

1.1 An overview

Sustainable urban development had broadcasting and collective interdisciplinary thoughts through time. Main approaches started in the 1970s and 1980s by the UN to define the future strategies for resources as a moral and physical commitment towards next generations, (Brundtland 1989; Pezzoli 1997a, 1997b). From an urban resource point of view, sustainability is not a complicated improvement of the post modern urban design pure artistic aesthetics rather than a functional vision of the urban space design and place making myths, (Jabareen 2006; Moughtin 1992).

However, despite the preparation for the urban sustainable development age in the 1980s, (Hoballah 2006; Selim 2008; UNDP and INP 2005; Zeitoun 1993), till now the two lines of sustainable urban design model and the post revolution urban modernism based on the socialist central housing plans and the theoretical values of post modernism urbanism didn't meet in a hot country like Egypt, (Ali 2003; Dona 1999; Fahmi and Sutton 2008; Stewart et al. 2004; Sutton and Fahmi 2001). The urban planning product from those two lines could be a passive sustainable treatment for urban patterns and form that might solve three main issues; accommodating people in acceptable houses, maintaining acceptable comfort level regarding people's acclimatization, and diverse urban forms.

1.2 Thermal comfort and sustainability

Among sustainability aspects of the built environment, is to close to indoor-outdoor comfort levels which in turn reduce, urban heat island effect, energy consumptions and cope with the global climate change, (McEVOY 2007). This paper concerns about urban thermal comfort which is difficult to assess due to the transient conditions of open environment. Nevertheless, it can be defined as the thermal sensation of a group of people in a specific built environment, (de-Dear and Brager 1998; Givoni 1998; Nikolopoulou and Lykoudis 2006).

The lake in application of climate knowledge due to complex interdisciplinary and intersected fields decreased urban climate studies dedicated to applied urban planning, (Ali-Toudert 2005; Arnfield 2003; Eliasson 2000; Oke 1984, 2006). On another hand, the theoretical physiological comfort model cannot support alone an actual sensation, (Nikolopoulou et al. 2001), nor to provide specific aesthetical values within urban context unless it is combined into an urban planning and design comfort model, (Fahmy and Sharples 2008b).

1.3 Urban sustainable forms

Urban form has raised as a crucial built environment issue from the late 1980s within governmental policies, (Allmendinger and Thomas 1998), due its direct effects on habitat, ecosystems, endangered species, water quality through land consumption, and replacement of natural cover with impervious surfaces. Moreover, urban form affects, the whole built environment systems, (EPA 2005). It is well documented that the more compacted form prevents wind access, increases population density and decreases green cover. Vernacular architecture in metropolitan Cairo is an example. Oppositely, the open fabric form with reduced height to width street canyons, single family housing in dot patterns of Cairo's master plan developments for example, overwhelms fabric surfaces with excessive heat gains, (Taha 1997; Pearlmutter and Shaviv 2005; Johansson 2006). Consequently, a medium population with reduced surfaces gaining heat is needed.

It can be argued that medium population planning provided by linear clustered form is a key issue as clustered form stands in between the open and the compact form from a land use point of view, (Fahmy and Sharples 2009a; Marcus and Sarkissian 1986). The linear form can support privacy for enclosed urban spaces, continuity, (DTLR and CABE 2001). The clustered fabric with medium population density can perceive a successful passive design form, (Oke 1988), and good thermal performance, (Bourbia and Awbi 2004), provide cooling effects, (Shashua-Bar and Hoffman 2004), and better performance if its proportions have been adjusted, (Muhaisen 2006).

(Jabareen 2006) defined sustainable forms in terms of seven issues;

1. Compactness.
2. Sustainable transport, (and also accessibility to facilities).
3. Density.
4. Mixed land uses.
5. Diversity.
6. Passive solar design.
7. Greening.

The sustainable forms that can provide urban comfort have taken much concern of research in the field of urban climatology (Ali-Toudert and Mayer 2007b; Eliasson 2000; Golany 1996; Landsberg 1973; Oke 1984, 2006; Swaid 1992). There was a utopia concerning what is the form that can perform well in each climate and what is the link between climate knowledge and urban planning. The rural and suburban patterns of a city are mostly open patterns whilst centre and core areas are more compact, (Duany 2002; Oke 2006). So, if medium population clustered patterns could control the form not to be a very compact to prevent wind access nor to be too open to provide solar shading, (Fahmy and Sharples 2008c), a question appear; is it an obligation to have fixed forms to achieve comfort? Does comfort based neighbourhood planning deliver a diversity of sustainable urban forms as an application for climate knowledge parallel with reducing thermal sensation and save energy?

2 Methodology

As a need to accommodate, a specific degree of compactness arises. Degree of compactness *D*c, as a link between climate knowledge and urban planning practice, is the average urban site height multiplied by the urban constructed area, (Fahmy and Sharples 2009a). Based on the experience gained from the new urban town developments of Greater Cairo, an assessment of quarter neighbourhood theoretical design, indicated how linear clustered pattern form, as medium population housing can thermally perform better. Two design sets were used applying basic neighbourhood planning concepts with parallel shaded and irradiated canyons. The first design set has two *D*c, but the second set has three to reach the population limit of law3, (Law3 1982), as it is the more detailed form after (Ali-Toudert and Mayer 2007b), and can provide more closure to comfort as a bigger scale of traditional courtyard. Simulations were held for three orientations 15°, 45° and 75°. The numerical simulation software, ENVI-met, (Bruse 2008), was used for assessing the comfort levels.

As thermal comfort is an important sustainability measure, urban diversity is another important measure. Increasing the compactness degrees by accommodating more population which in turn increases average canopy layer height (average site height) can reveal in better performance as the more detailed clusters were used. The shadows generated from these details and the increased canopy height decreases the total heat budget of urban canyons and spaces.

To assess the urban form degree of diversity three factors can be presented; first is the ratio of whole site facades' surface areas including openings to the whole site area. It stands for the diversity of pedestrian visual perspectives due to the differentiated skylines and facades. Quantitatively, the more fabric facades' surfaces, the more degree of diversity. Moreover, increasing number of cluster fragments offer more walking tendency in an intensely various closes with pedestrian approaches, urban places and scenes, (DTLR and CABE 2001; Jacobe 1961).

Second factor is the urban context. A simple master plan graphical analysis for urban private-public spaces has been performed to assess urban spaces. For simplicity reasons, the zoning and focal points for all of them are the same based on pedestrian linkage axial concept over a grid pattern in order to restrict urban diversity only to the *D*v factor. All cluster forms of the design sets imported 3-4 distinct fabric forms, 3 different shapes of urban places in addition to the green avenues and the civic centre of the quarter neighbourhood. Eventually, an adhesive urban habitat would be established.

(Day 2003) argued for more housing typologies to account for urban diversity which considered as the third indicator in this work, but it hasn't been counted to affect the diversity for any design set to base the work only on clusters details effects. However, all of sets are based on a 150 Sq.m. unit/family that can be horizontally or vertically doubled to increase housing unit area and generate diversity of housing types.

To study how can urban diversity affected by passive design, human thermal comfort perception at 30° 7'N and 31° 23'E for 9 selected points 1.2m above ground level was assessed using the predicted mean vote scale *PMV*, (Heidari and Sharples 2002; Humphreys and Nicol 2002; Jendritzky and Nübler 1981; Olesen and Parsons 2002). The 26th of June, the extreme hot day of Cairo's summer, (ASHRAE 2005), was simulated for 6h from 11.00-16.00 LST to investigate the extreme comfort levels.

3 Results;

Table no.1 illustrates the planning indicators for the 9 points for 3 orientations of the 5 design sets. Fig.1/a, b, c is mapping of all sets' sheltering behaviour against direct solar radiation illustrated over each set master plan 1.2m above ground level when solar altitude is 83.3° at 13.00 LST. The less grey area, the less solar access whereas up on the scale means the reduce amount of W/m2 gained at this level.

All maximum *PMV* values are either at 12.00 or 13.00 LST due to the solar altitude direct gain. All minimums reported in the cluster courtyards wings at 16.00 LST. Among Set1, the minimum *PMV* values recorded for a pattern orientation was 3.21 for Set1_Dv1_45° at which *D*v is 0.50 which is the minimum *D*v recorded. By increasing *D*c from 0.84 to about 1.04, *D*v increased to 0.65 at which the minimum *PMV* inside clusters stayed around the 45° orientation.

In Set2, the *D*c stayed 1.04 but design details tremendously doubled *D*v to 1.27. This moved the minimum recorded *PMV* value to be 3.07 at Set2_Dv1_15° then to 2.73 at Set2_Dv2_75° of *D*v 1.62 due to increasing *D*c to 1.30.

The minimum *PMV* was 1.90 at 16.00 LST of Set2_Dv3_75° which has the maximum *D*c of 1.549, *D*v of 2.25. Urban form design details increase the urban diversity quantitative factor *Dv* as described. Comparison between the compactness and diversity degrees against *PMV* is shown in fig.2. Table no.1 also shows a direct proportional relation between *D*v and *D*c for all design sets.

Table (1): Housing and sets' urban planning parameters;

	Design set name	Site area in feddans	% of Green coverage area	% Urban construction	Average no. of site floors	Compactness degree, *D*c	Diversity degree, *D*v	person/feddan	Law no.3
1	Set1_Dv1	51.07	0.25	21.8	3.88	0.84	0.50	82.2	100 -150 p/fed
2	Set1_Dv2	51.07		21.8	4.75	1.04	0.65	103.4	
3	Set2_Dv1	37.24	0.18	26.5	3.92	1.04	1.27	115.2	
4	Set2_Dv2	37.24		26.5	4.92	1.30	1.62	124.5	
5	Set2_Dv3	37.24		28.0	5.85	1.55	2.25	143.4	

- Facilities buildings at service civic centre are 10m height in all design sets and 13 m in Set2_Dc2, 3 to increase facilities.
- The actual residential land use can be calculated after extracting 33% for the network and green coverage as (Law3) tells, also after extracting the civic buildings plot areas, hence the residential land use for example for Set2_Dc3 is 23.707 feddans is 63.66% of site area, i.e. the actual constructed area which is 10.428 feddans gives construction percentage of 43.99 %.
- Feddan = 4200 sq.m.

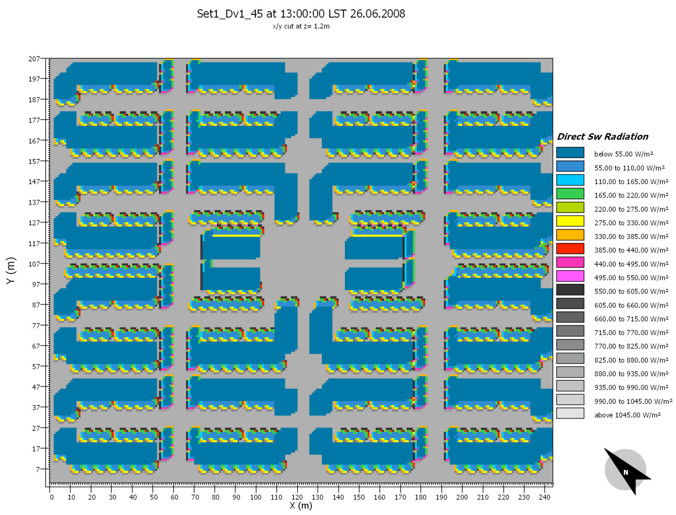

Fig. 1/a. direct radiation of Set1_Dv1_45° at 13.00 LST, 1.2m a.g.l.

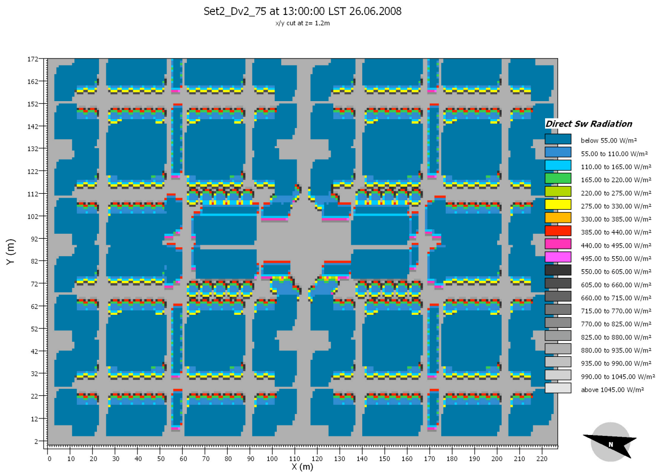

Fig. 1/b. direct radiation of Set2_Dv2_75° at 13.00 LST, 1.2m a.g.l.

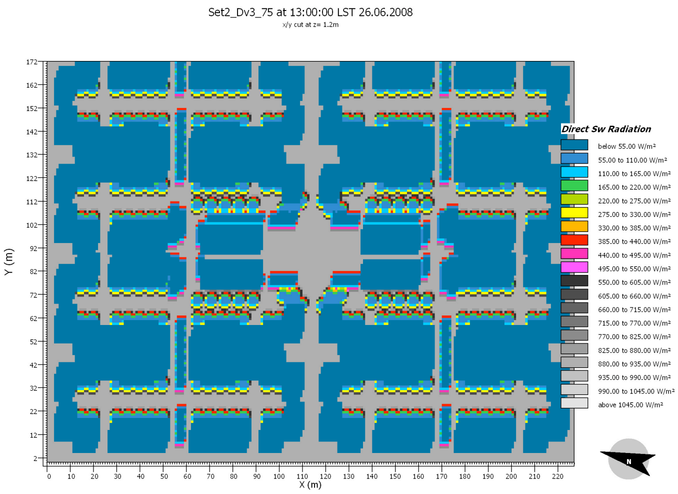

Fig. 1/c. direct radiation of Set2_Dv3_75° at 13.00 LST, 1.2m a.g.l.

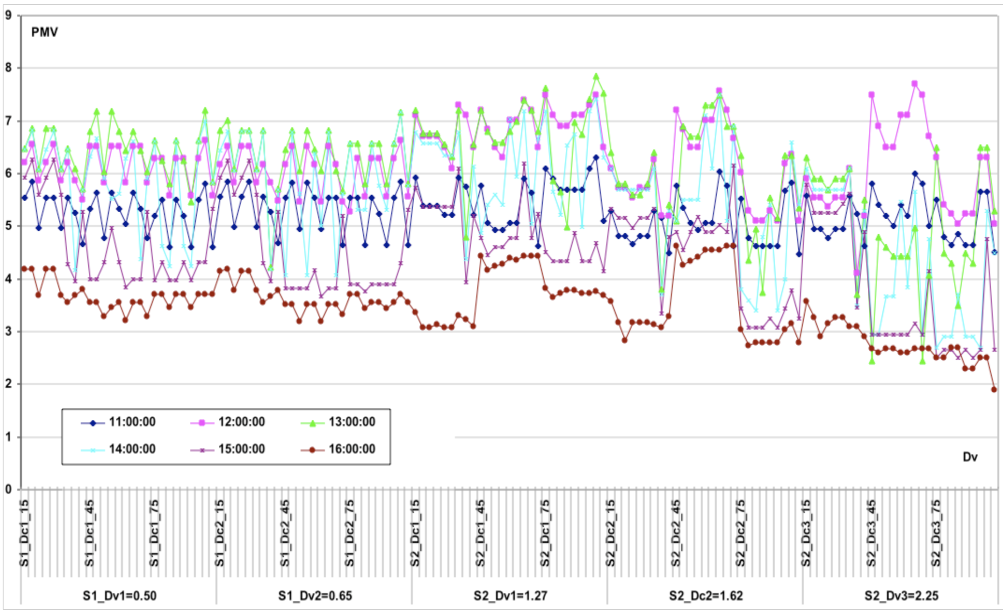

Fig.2: Plotting of PMV against Dv, for the 9 points in each orientation of each set.

4 Discussion: Comfort and degree of diversity

One can think that medium population clusters are blocks just like the international style of the mid last century, this paper is not revisiting the socialist urban planning rather than a search for thermal comfort sustainable forms. The utopia of comfortable communities especially in hot regions tends to condense the fabric but caution should take place to both sheltering from wind as well as radiation.

In other words, as sustainable form measure diversity, the fear was that the climate based form converts to blocks and loose points on the sustainable from measure of diversity. The usage of past residential blocks came as a need to accommodate without any concern about urban thermal behaviour; examples can be drowned from many places, (Ladd 2001; Tsenkova 2004).

Herein this paper, results show that while Set2 performed better comfort levels inside and outside urban clusters used. Its clusters details that helped improving comfort levels also kept urban scenes, skylines and surfaces at diverse levels in terms of increased whole site facades areas. Facades' areas represent more or less varieties of pedestrian visual perspectives. This didn't contribute to more heat gain from direct radiation due to the orientation and the compactness of the form.

Set2_Dv3 showed a value of 2.25 which means more than double of the urban site area and reported the better comfort levels. But, no. of average floors achieved to reach the population limit of Egyptian urban planning law and increase *Dc* is more than law106, (Law106 1999), states for some street canyon aspect ratios in Set2. Consequently, Set2_Dv2_75° of 1.62 is the preferable degree of diversity regardless the higher PMV value which can be decreased by other passive techniques out of the scope of this paper.

5 Conclusion

Investigated in this paper, how urban form can keep urban diversity as an important measure for sustainability at local urban planning scale. Simulations were performed to assess a quarter neighbourhood comfort based design effects on providing diversity. Urban form diversity can be presented in three factors; the degree of diversity, urban context and housing typologies. The latter two factors have been fixed in order to study the effect of the first one, the degree of diversity, *D*v. The degree of diversity can be defined as the ratio of all form facades' areas to the total area of urban site and it is directly proportional with the degree of compactness. Results conducted that, whilst the detailed form is a response of urban passive utopia search for cooling in hot regions, comfort provision not only helps thermal sustainability but also urban diversity.

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