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Extensive review for urban climatology: definitions, aspects and scales.

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Abstract;

There are many energy budget models and classifications of urban climate layers, field measurements, simulations and researches in the field of urban climatology that concerns about the mutual impact of climate and urban form, (Landsberg, 1973), (Oke, 1984), (Mayer and Hoppe, 1987), (Golany, 1996), (Schiller and Evans, 1996), (Eliasson, 2000), (Arnfield, 2003) and (Oke, 2006). Although there is a magnificent progress in the field, but some few promising world wide projects (Oke, 2006), and some design studies and methodologies (Bitan, 1988), (Pearlmutter et al., 1999) and (Ali-Toudert and Mayer, 2007), the application for that knowledge still away from the urban form sensitive design, because they have been done from the physical, mathematical and meteorological points of view but haven't been investigated till now from the applied urban planning and design point of view specially at local scale of a neighborhood climate. The need is for all parties of the urban field as in real process, the scientific circle won't be closed without the architects, urban designers, planners, Econo-sociologists and psychologists' participation in the model. However this extensive paper is prepared to introduce this large field of knowledge about how to design urban fabric and patterns in accordance to climate aspects and its scales of application along with definitions concerning human thermal comfort in the field.

Introduction: Briefing for literature and research approaches;

Yet it is complex relations to investigate that of the climatology, meteorology, built form, with the microclimate scale of urban planning patterns, consequently how can we imagine solving that complexity of a local climatology scale to assess urban thermal comfort which has been illustrated to be certainly unachievable 100% from any single mean point of view without broadening the scope of research due to urban mobility of climate conditions. It is not only from physiology calculation of heat balance, not only from human thermal regulatory with metabolism and clothing adjustments, not only with the behavioral adjustments, not only by physical environmental adjustments and passive sensitive design, but with all of these techniques, methodologies, sequences and applications that have to apply specific interdisciplinary geometrized tools of Pysio-Psychological thermal comfort adaptation to form a fabric.

Such a definition of model defines at the same time the objective of the great work in urban climatology-meteorology fields, from the microclimate scale to mesoscale.

The need is for a model utilized tools to translate all of this knowledge to the realm, an ordinance to regulate the fabric form that is capable of controlling the canopy layer climate by delivering opportunities for people to obtain their own thermal comfort and indices, the need is for an urban planning and design model.

Although a lot of researches studied before about the built and the natural environment, the fact that environmental control means all of environmental criteria, planning and design, thermal comfort design still an important branch of the total environmental design and planning.

1- Urban thermal performance:

The urban structure (built form + pattern) interacts with its climatic circumstances in a behavior due to outdoor heat transfer and heat exchange in between urban canyons and its interior elements. And the urban form is acting like the building acts in such an action we can call it *breathing*, it has incident sun rays then heat absorbed or reflected, the absorbed amount of heat has another amount to be emitted after certain time in which the air flow temperature come down, this is the physical thermal motion which can be called the *breathing* of the urban canyon, figure (1) illustrates the motion of heat. The compliance of this physical behavior of built fabric is the thermal interactions of human and vegetation.

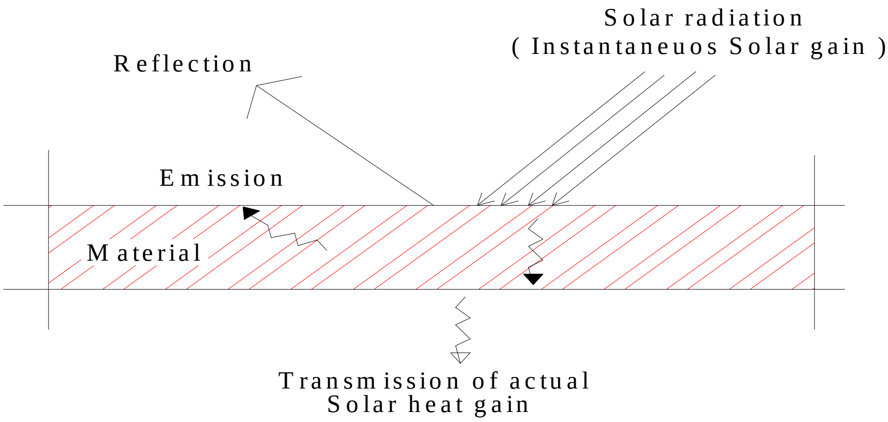


Figure (1): The heat transfer routes through materials, (Fahmy, 2001)

2- Review for thermal comfort evaluation indices:

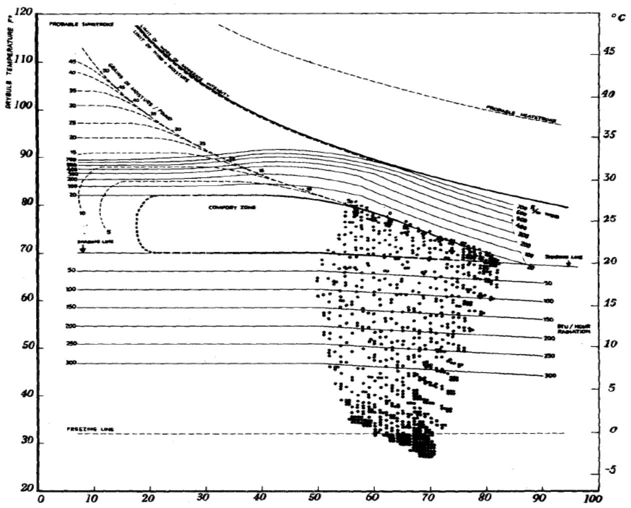
There are many evaluation indices for the thermal state of interior or exterior places for human comfort as it is a need to know the place where in door or outdoor design is far from perfection. Some of those indices are optimum to be used indoor and others to be used outdoor (Givoni, 1998) , they are more than 100 thermal comfort indices, (Jendritzky et al., 2002) , some of them are just indices of relations between meteorology parameters such as air temperature plus wind speed in cold climates or air temperature plus humidity in hot climates but are criticized as the bioclimatic chart for Olgyay that has some differences for the limits of comfort zone if applied outdoor and can’t be used correctly at all of the climatic regions because Olgyay experienced his field measurements at indoor circumstances in a humid region. Other indices are considering a total thermo physiological heat exchange and balance models to be indexed. Those later can be divided into two parts; first is so called steady state heat budget models that have been introduced for indoor purposes (Hoppe, 2002) but doesn't consider for example air speed in model calculation and revealed in non-compatible field measurements indices like PMV (Brager and De Dear, 1998) and (Humphreys ad Nicol, 2002) . Second type that are models for passive indoor or outdoor circumstances evaluation and considering part of or the total budget [all net fluxes and exchange within fabric starting from (Nunez and Oke, 1977), human heat exchange (Pearlmutter, 1999), vegetation heat exchange (Kum, Bretz, Huang and Akbari, 1994), urban anthropogenic heat gain (Taha, 1997)] of an urban space represented in a symmetric or an asymmetric urban street canyon field measurements, simulations or metreological referencing to indoor comfort conditions with some transient conditions such as OUT_SET, PET, introducing air speed of 0.1 m/s or similar (Mayer and Hoppe, 1987), that is called numerical models as modifications to the PMV heat balance model and index rather than a canyon total heat budget model calculation such as ENVI-met (Bruse and Fleer, 1998)[1] and (Bruse, 2008) that is capable of calculating all heat transfer interactions, wind flow turbulences of the built environment and human heat exchanges in terms of the mean radiant temperature despite its dependence on the modified PMV index of climate evaluation (Jendritzky and Nubler, 1981) and despite some overestimations because of un-calculating soil heat storage (Ali-Toudert, 2005) that make this model also less estimating the nocturnal cooling or earth long wave radiation. Fortunately, an urban comfort index should be redefined as thermal comfort model itself has to be redefined (Nikolopoulou and Lykoudis, 2006) in terms of a design model that combines approaches, tools, techniques and applications of urban fabric design parties, specializations and design details. A briefing for most known thermal comfort indices is tabulated as following:

Table (1): Briefing for some of thermal comfort indices:

a- Meteorology parameters indices:		
	Index name	Brief
1	Bioclimatic chart	A graphical tool for plotting meteorology and assigning comfort zones for different regions in terms of T_a and *RH* (Olgyay and Olgyay, 1957) and (Olgyay, 1967), figure (2).
	Mahoney bioclimatic tables	They are for recording and recommendation as following: (1) The max, min, and mean air temperature for each month. (2) The max, min, and mean figures for each month RH, Rainfall, and Wind and the conditions for each month classified into a humidity group. (3) Comparison of Comfort Conditions and Climate. The desired max/min temperatures are entered, and compared to the climatic values from table 1. A note is made if the conditions create heat stress or cold stress. (4) Indicators (of humid or arid conditions). Rules are provided for combining the stress (table 3) and humidity groups (table 2) to check a box classifying the humidity and aridity for each month. For each of six possible indicators, the number of months where that indicator was checked is added up, giving a yearly total. (5) Schematic Design Recommendations. The yearly totals in table 4 correspond to rows in this table, listing schematic design recommendations, e.g. 'buildings oriented on east-west axis to reduce sun exposure', 'medium sized openings, 20%-40% of wall area'. (6) Design Development Recommendations. Again the yearly totals from table 4 are used to read off recommendations, e.g. 'roofs should be high-mass and well insulated', (Koenigsberger, et al., 1970).
2	Effective Temperature (ET)	It is presented in Monograms and represents the instantaneous thermal sensation estimated experimentally as a combination of T_a, *RH* and v, ASHRAE (Ashrae-55, 1981).
3	Psychrometric chart	A graphical tool for plotting meteorology and assigning comfort zones for different regions in terms of *DBT, WBT, RH, VP*,…etc (Givoni, 1969).
4	Comfort triangle	A graphical tool for evaluating temperature variations, (Evans, 2003)

		and (Evans, 2007), figure (3).
5	wind shell index, (WCI)	Combining T_a and V for outdoor cold conditions, (Siple and Passel, 1945), (Osczevski and Bluestein, 2005) and (Shitzer, 2007), figure (4).
b- heat balance indices:		
1- steady state indices:		
	Index name	Brief
	Fanger equation, (PMV)	PMV expresses the variance of comfort on a scale from -3 to +3 for an indoor balanced human heat budget, (Fanger, 1972).
2- transient state PMV based heat balance indices:		
a	Index of thermal sensation ITS and TS, the thermal sensation index	It considers the heat exchanges, metabolism and clothes, where it wasn't Originally considering the radiation exchanges assuming that within the range of conditions where it is possible to maintain thermal equilibrium, sweat is secreted at sufficient rate to achieve evaporative cooling, later the TS proposed a modified Thermal Sensation Index for outdoors, (Givoni, 1963), (Givoni, 1969) and (Givoni et al., 2003).
b	Perceived temperature (PT), The new effective temperature (ET*), The Standard Effective Temperature (SET*), The Outdoor Standard Effective Temperature (OUT_SET*), Physiologically Equivalent Temperature (PET).	The thermo-physiological assessment is made for a standard male whom has varying clothing and activity or work within a standardized environment and depending on the base of PMV, based on a complete heat budget model describing the physiological processes that provide reference environment in which heat fluxes would be the same as in the actual environment. Mean radiation temperature is equal to air temperature and calm with varying wind speed from 0.1 m/s of the PET to 0.15 of the ET*, SET* and OUT_SET*, 50% RH with a temperature of 20 °C. PT and PET are closely correlated with r = 0,995, (Jendritzky and Nubler, 1981), (Gagge et al., 1986), (Mayer and Hoppe, 1987), (Hoppe, 1999), (Ali-Toudert, 2005) and (Monteiro and Alucci, 2006). The Universal Thermal Climate Index UTCI is an ongoing project considering the UBIKLIM model based on a Physiologically Significant Terms to achieve urban thermal comfort, (Jendritzky et al., 2002) and (Hoppe, 2002).

Figure (2): The bioclimatic chart, (Olgyay, 1967).



. The average yearly climatic conditions of the New York-New Jersey area are plotted on the Bioclimatic Chart. Each point represents hourly data over 10-day periods throughout the year. In the middle of the chart is the comfort zone and from the perimeter of it are registered the climatic elements needed to restore the feeling of comfort (Olgyay and Olgyay, 1957)

Figure (3): Martin Evans triangle graphical tool for bioclimatic design as presented in (Evans, 2003), it depends on a temperature dissection over four points on a Trombe mass wall depending on a simple equation to calculate the temperature variation and the equivalent temperature from the external temperature that is provided from metrological sources: $T_{eq} = T_{ext} + I.\alpha.r_e$; where ($I$) is the radiation flux in w/m2, (α) is the coefficient of absorption and (r_e) is the thermal resistance is the external.

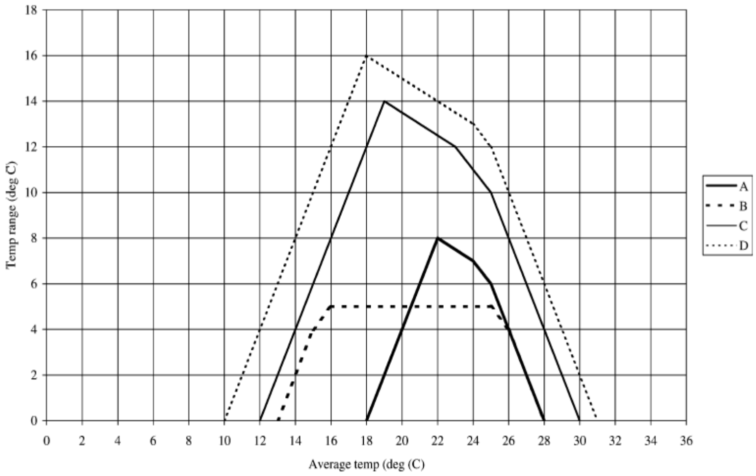


Fig. 1. The comfort triangle with zones for sedentary comfort (A), right comfort (B), indoor circulation (C) and outdoor circulation (D).

mph. Here, WCT = 35.74 + 0.6215T – 35.75$V^{0.16}$ + 0.4275$TV^{0.16}$. Shading indicates temperatures at which frosbite can occur.

Temperature (°F)

Wind Speed (mph) / Calm	40	35	30	25	20	15	10	5	0	–5	–10	–15	–20	–25	–30	–35	–40	–45
5	36	31	25	19	13	7	1	–5	–11	–16	–22	–28	–34	–40	–46	–52	–57	–63
10	34	27	21	15	9	3	–4	–10	–16	–22	–28	–35	–41	–47	–53	–59	–66	–72
15	32	25	19	13	6	0	–7	–13	–19	–26	–32	–39	–45	–51	–58	–64	–71	–77
20	30	24	17	11	4	–2	–9	–15	22	–29	–35	–42	–48	–55	–61	–68	–74	–81
25	29	23	16	9	3	–4	–11	–17	–24	–31	–37	–44	–51	–58	–64	–71	–78	–84
30	28	22	15	8	1	–5	–12	–19	–26	–33	–39	–46	–53	–60	–67	–73	–80	–87
35	28	21	14	7	0	–7	–14	–21	–27	–34	–41	–48	–55	–62	–69	–76	–82	–89
40	27	20	13	6	–1	–8	–15	–22	-29	-36	–43	–50	–57	–64	–71	–78	–84	–91
45	26	19	12	5	–2	–9	–16	–23	–30	–37	–44	–51	–58	–65	–72	–79	–86	–93
50	26	19	12	4	–3	–10	–17	–24	–31	–38	–45	–52	–60	–67	–74	–81	–88	–95
55	25	18	11	4	–3	–11	–18	–25	–32	–39	–46	–54	–61	–68	–75	–82	–89	–97
60	25	17	10	3	–4	–11	–19	–26	–33	–40	–48	–55	–62	–69	–76	–84	–91	–98

Figure (4): The new wind chill chart, adopted as table from (Osczevski and Bluestein 2005).

3- Urban heat stresses:

The urban climatology is a very complicated issue regarding unstable climate conditions especially at canyons intersections and roof levels. 'Urban volume doesn't end at limits of canyon ceiling', (ISL) is extended to about 2-5 times the height of urban buildings (D. Pearlmutter et al, 2007). The early study of

There are three main urban volume layers that holds the climate interactions which are, (Oke, 1976), figure (5/a, b, c):

1- The urban canyon layer (UCL) that has the street level microclimate circumstances.
2- The urban boundary layer (UBL) that has the inertial surface roughness sub-layer (ISL) as an envelope for urban roofs.
3- Urban air dome layer that has the regional mesoscale climate conditions.

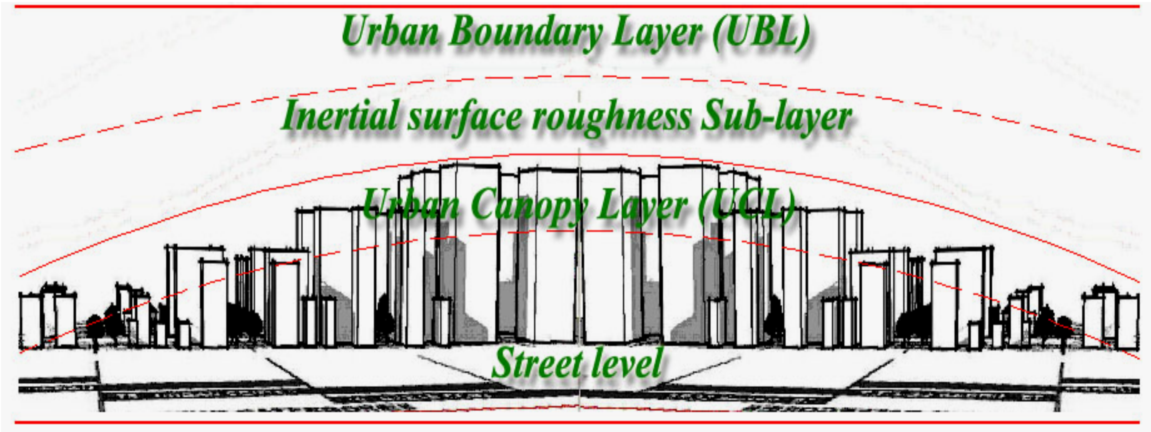


Figure (5/a): Relation of urban climatology layers.

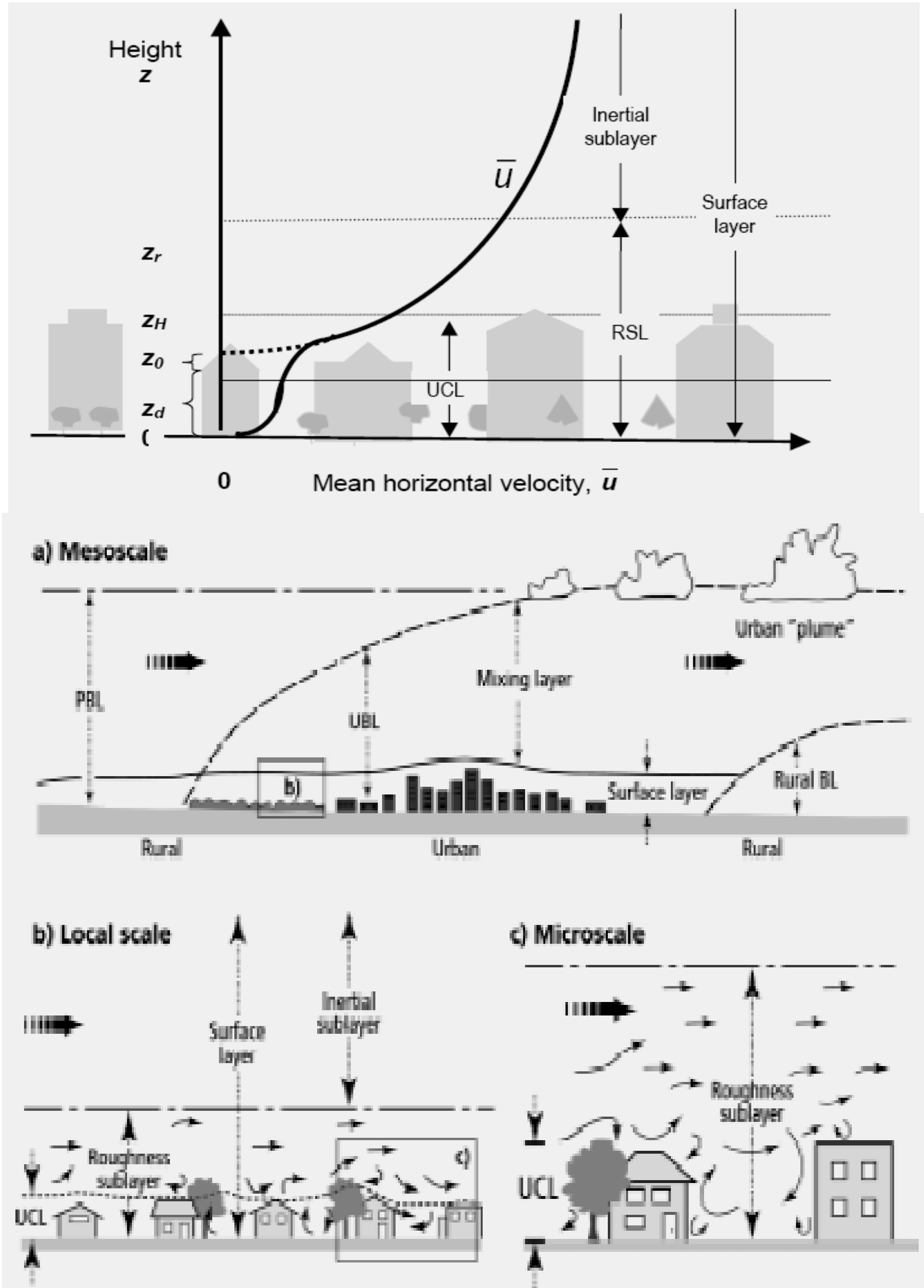


Figure (5/b): Wind profile and urban climatology layers, (Oke, 2006).

The heat transfer circles are due to the following, figure (5/b):

1- Radiant heat exchanges in between human and canyon surfaces and in between canyon surfaces itself.
2- Convective heat exchanges between canyon surfaces due to reflections and emissions.
3- Heat generation within homogeneous patterns (i.e. a continuous pattern which is not separated by highways or regional roads), that heat if trapped, it is called heat islands.
4- Up/down air flows within the three levels of urban spatial layers.

One of the challenges of urban climatology is in the climate change which is an important parameter in future energy consumption, calculations and all related issues of urban thermal comfort and urban passive sensitive design. The scenarios of facing climate change are, (McEVOY, 2007):

1- Increasing power resources to cope with future needs which are considered very hard and expensive regarding the globe conflicts and natural resources expiry.
2- Facing a great decrease in the national outcome due to leakage of power supply needed to maintain social, economical, industrial progress and prosperity.
3- *A smart growth scenario in combination with tackling the renewable sources seriously, urban and buildings passive designs opportunities by urban thermal design to encouraging people to adapt their local and national thermal comfort indices and decreasing mechanical needs.*

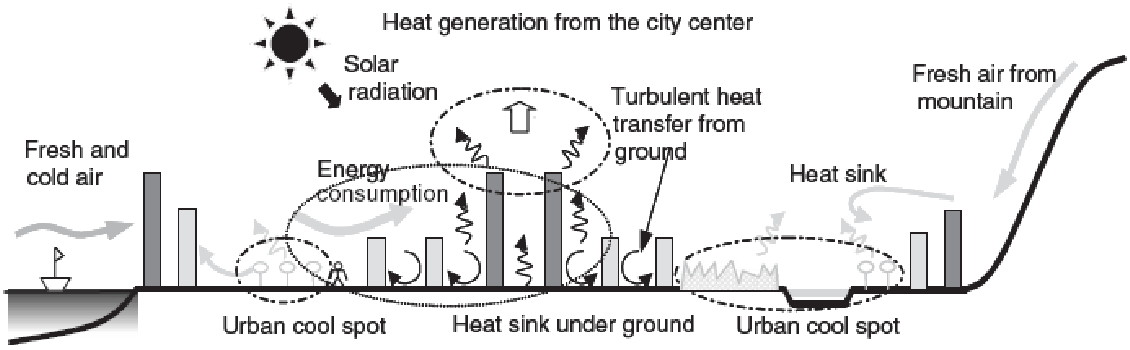


Figure (5/c): Heat exchange in between urban components, (Murakami, 2005).

A series of studies held by (Oke, 1976), (Oke, 1987) and (Roth, Oke and Emery, 1989a) said that "Almost universally, the modified thermal climate is warmer, giving rise to the urban heat island", but effect of urban climate change at street level can be mitigated in terms of passive treatments and applications to answer an important question:

- *Does the urban canyon geometry, MPUS elements' geometries and geometry distribution of urban Greensect of an empirical passive urban pattern meshed allover the main urban planning patterns have to be identified and accurately engineered, geometrized and plotted on the community layout physical form as a network of an empirically induced urban passive cooling systems to lay LUHIs under siege of cooling nodes*? *And off coarse the development of that passively designed and planned urban pattern should consider the percentages of annual climate change in weather data in order to design and plan that passive pattern for a sustainable smart growth vision.*

4- Canyon heat exchange, balance and wind flow:

The heat exchange happening between a human body and other surrounding bodies in regard to the climatic conditions is responsible for the human heat balance in his environment which has been studied as a radiant and convective energy balances firstly by (Monteith, 1973) whom had provided a vertical cylinder to simulate a man standing on the ground level of an urban canyon to account the exchange between it and the environment where all fluxes were in w/m2 of the cylindrical (still conditions i.e. body is not moving) body to measure and calculate the instantaneous net radiant heat exchange (R_n).

(Nunez and Oke, 1977) investigated the basic knowledge on the energy balance of urban canyon in their experiment in Vancouver.

The study dealt with a street located in Vancouver (49° N), N-S oriented, with an aspect ratio (H1/W = 0.86 and H2/W= 1.15). The net all-wave radiation of both walls and floor were explained as sensible heat fluxes Q_H, latent heat fluxes Q_E and energy stored in materials ΔQ_S explained by (Ali-Toudert, 2005) as follows:

$$Q^{*}_{Wall} = Q_H + \Delta Q_S \qquad (1)$$

$$Q^{*}_{Floor} = Q_H + Q_E + \Delta Q_S \qquad (2)$$

The main conclusion was that orientation is responsible for canyon heat budget. All energy components were measured during three days, but the sensible heat flux which was obtained as residual. The main results were:

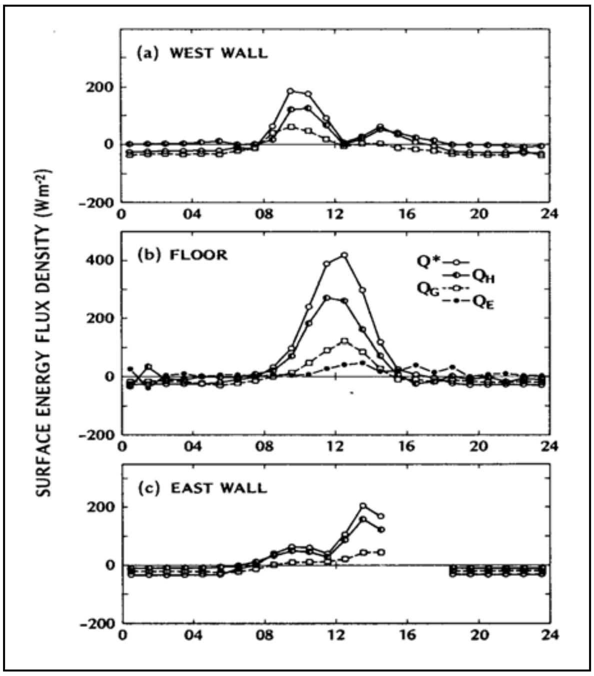
1- Canyon geometry has an influence on the radiation exchanges affecting the timing and magnitude of the energy mechanism of the individual canyon surfaces and was very different from each other.

2- The orientation had an evident importance on the energy balance where the air turbulence affects the heat storage.

Figure (6/a, b) illustrates the canyon and its diurnal mechanism of all fluxes for the floor, the east-facing wall and the canyon-top for the Vancouver experiment. The east-facing wall is first irradiated in the morning and the second peak in the afternoon due to the diffused radiation mainly reflected from the opposite wall that delivers a maximum irradiation at that time. According to the N-S orientation, the floor is exposed at midday, the west and east walls about 1.5 hours before and after solar noon, where about 60% of the radiant energy surplus was dissipated as a sensible heat flux, 25-30% stored in the materials and 10% transferred to air as latent heat. In the night-time the net radiant deficit is offset by the release of the energy stored within canyon materials and turbulent exchange which is minor. Nunez and Oke suggested that directing airflow at an angle in relation to canyon axis is important to pattern design. (Nakamura and Oke, 1988) investigated the spatial distribution of air temperature within an urban canyon with a network of 63 measuring points was set in a vertical cross-section of an urban canyon located in Kyoto, Japan, in a summer clear days. It was arranged with an increasing frequency towards the floor and walls to draw a thermal map for Kyoto canyon. A near to (Nunez and Oke, 1977) conclusions were made by (Mills and Arnfield 1993), (Mills, 1993), (Santamouris et al. 1999), (Ali-Toudert, 2005) and (for different shapes of canyons measured or simulated with different orientations and aspect ratios.

Heat exchange takes place between the three of human body, surroundings and with air due to direct incident sun rays, its reflections and diffusions, i.e. surfaces' mean radiant temperature, determines the amount of heat exchanged.

The interactions of heat exchanges due to radiation and convection with human and surrounding environment were investigated in an open air empirical physical model using varieties of canyons combinations and orientation with manikin for human and it was mainly concluded that compact forms of canyons deliver cooled environment and dramatically modifies pedestrian comfort by the canyon geometry.



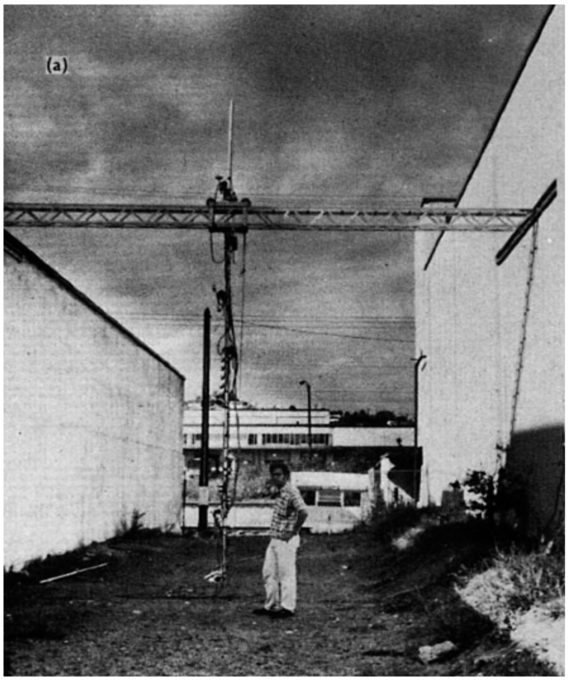


Figure (6/a, b): c; The actual conditions of the canyon experiment held by (Nunez and Oke, 1977) illustrating the structure that carried the sensors, d; Diurnal energy balances for each of the canyon surfaces in three days.

Figure (18/a) by (Pearlmutter, Bitan and Berliner, 1999), (Pearlmutter and Shaviv, 2005), (Pearlmutter et. al., 2006) and (Pearlmutter et. al., 2007) illustrates:

1- *Radiant heat exchange*:

It is measured as mentioned by calculating the equation;

$$R_n = (1-\rho_s)(G_{dir} + G_{dif} + \rho_h G_h + \rho_v G_v + L_d + L_h + L_v - \varepsilon\sigma T_s^4 \qquad (3)$$

where;

R_n:	*The net radiation; all wave lengths in w/m2.*
ρ_s :	*The Albedo of skin (body surface).*
G_{dir} :	*Direct incident radiation on body.*
G_{dif} :	*Diffused incident radiation on body.*
$\rho_h G_h$:	*Solar radiation reflected from horizontal surfaces.*
$\rho_v G_v$:	*Solar radiation reflected from vertical surfaces.*
L_d :	*Total downward long-wave radiation emitted by atmosphere.*
L_h :	*Total upward long-wave radiation emitted by ground.*
L_v :	*Total upward long-wave radiation emitted from verticals.*
ε :	*The emissivity of the body.*
σ :	*Stepfan-Boltz man constant.*
T_s^4 :	*Average temperature of the body.*

An assumption for the surfaces reflectivity is considered when laboratory or field measurements are held for certain surfaces, direct and diffused components of sun radiation can be estimated from the measured global radiation and sky clearance. Values for the skin surface area (Albedo) are due to the color and texture.

2- *Convective heat exchange*:
(Mitchell, 1974) calculated the rate of convective heat transfer (*C*) or the sensible flux and measured it in w/m2 as following;

$$C = h_c \Delta T \quad (4)$$

Where:

C	:	*The convective heat transfer or the sensible flux in w/m2.*
h_c	:	*The convective transfer coefficient in w/m2.c, which is dependent on number of people in a group that affect the forced convection and on the air speed.*
ΔT	:	*Difference between body temperature and the surrounding air temperature.*

3- The conductive exchange could happen theoretically if the person is touching or sitting, this could by;

$$C = K_c \Delta T \quad (5)$$

Where:

C	:	*The conductive heat transfer flux in w/m2.*
h_c	:	*The conductive transfer coefficient in w/m2.c, which is dependent on material physical properties.*
ΔT	:	*Difference between body temperature and the material temperature.*

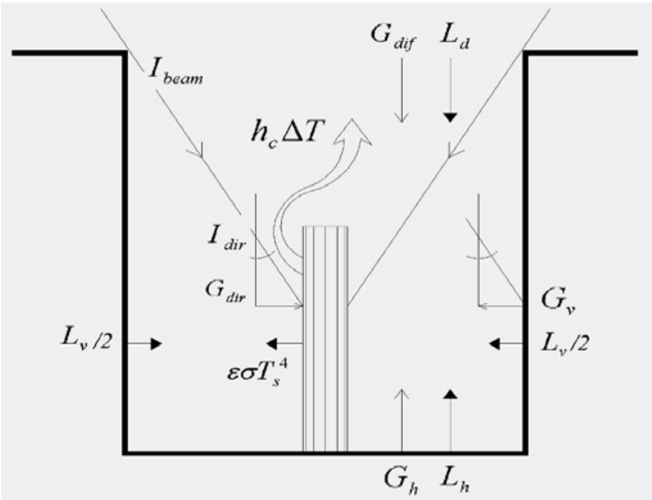


Figure (18/a): Heat exchange between cylindrical body (represents human) and its canyon environment, where canyon is the U shape of a street cross section, (Pearlmutter, Bitan and Berliner, 1999).

The canyon's wind flow characteristics is derived from the wind flow of the ISL above the canopy layer which is greatly affected by the canyon orientation, slope and geometry and the surrounding pattern geometry which is represented in term of the building form ratios, H/W, H/L (Oke, 1988), S/V (Matteoli, 1982) figure (7/c), and H/W/L (Waziry, 2004), where (Ali-Toudert, 2005) and (Ali-Toudert and Mayer, 2006) concluded that urban thermal comfort despite its impossibility to achieve, can be gotten closer by fabric design. Those characteristics can be demonstrated as following:

1- Air flows over an urban pattern near to the normal direction over street axis are three types of flow systems depending on the buildings and pattern geometry and their specific combinations; figure (7/b).
2- Those three air flow mechanisms can be described when H/W is large, medium or small magnitude; (a) the first case called isolated roughness flow due to non-interaction of air, (b) by increasing of H/W interaction begins by slight separation of canyon's air from the (ISL) wind and a single vortex appears, (c) double vortices produced due to increasing H/W and high separation from the (ISL), (Santamouris et. al., 1999) and (Nakamura and Oke, 1988).
3- Air flow mechanisms are formatted upon the aspect ratio of canyon geometry, the construction density of whole surrounding urban pattern that is represented by construction density a/A or by describing the distances between buildings L1.........Ln, orientation Z, street level slope P, and the latitude T.
4- The difference between surface and air temperatures in urban canyons can be affected strongly by wind, in Kyoto's canyon $(T_S - T_A)$ was found to be about 10° in the midday and it declares local air movement from the low temperature areas at rooftop to the high temperature areas deep the canyon, beside a double vortex is a conclusion of parallel actions; stratification of the air temperature in canyon and the increased wind speed upon the canyon at (ISL), figure (7/ d).
5- The speed of a single vortex due to skimming wind regime of normal (H/W=1) canyon rooftop wind direction, (Hussein and Lee, 1980) results from three definite sources: the air flow upon the canyon, the vertical layers of air inside the canyon, and the mechanism of advection from the buildings ends, (Ali-Toudert, 2005), where irregularities of canyon aspect, direction and asymmetries reveals in canyon's wind form and direction disturbances, (Nakamura and Oke, 1988).
6- The relation between wind direction over rooftop and in canyon ground can be demonstrated as following:
    a- For a normal rooftop wind direction the canyon wind direction is opposite and vice versa.
    b- For rooftop wind direction same to the canyon axe the canyon wind direction is same direction of rooftop due to channeling effect.
    c- Most interesting is the intermediate case when flow above the rooftop has an angle-of-attack to the canyon axis. This produces a spiral vortex along the length of the canyon due to cork-screw type of wind action.
7- For the wind speed relations, the main one is the rooftop and the secondary is the canyon one, so for rooftop wind speed 1.5-2.0 m/s threshold canyon wind starts to be generated not scattered while for 5m/s rooftop wind speed the relation between the two speeds become nearly linear for H/W=1.4, (DePaul and Shieh, 1986).
8- The relation between the two wind speeds where concluded from previous researches and experiments to be $V_{Canyon} = 0.666 V_{Roof}$ for canyons winds are measured at about 0.06H and rooftop winds 1.2H, V_{Canyon} is the canyon wind speed and V_{Roof} is the wind speed above rooftop for V_{Roof} more than 5m/s for average rooftop windward direction to the canyon, (Nakamura and Oke, 1988). Similar coefficients for hot climates can help in fabric design.

9- From the above standing points, research can reintroduced the idea of a court yarded pattern in terms of clustered fabric that is arranged in a shaded and irradiated surfaces of canyons same as the double court ventilation concept of the Arabian housing to stimulate air movement while orienting canyons' axes angled to the prevailing wind, so that an assumption of this angle to be 30, 45 and 60 degrees is preferable and will be examined in chapter four in parallel to passive urban fabric and pattern design tools, refer back to figure viii/a and b of the introduction.

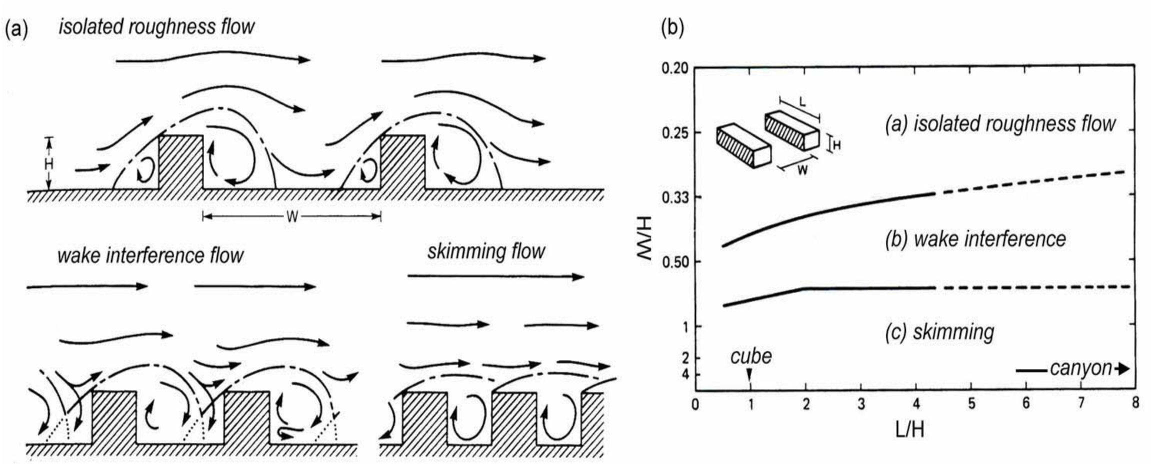


Figure (7/b): (a) Wind flow regimes (Oke, 1988), and (b) corresponding threshold lines dividing air flow into three regimes as function of canyon (H/W) and building geometry that can be defined either by construction density a/A where a is the roof area of a building and A its total plot area, or by S/V where S is the building surface area and V is the building volume (Matteoli, 1982).

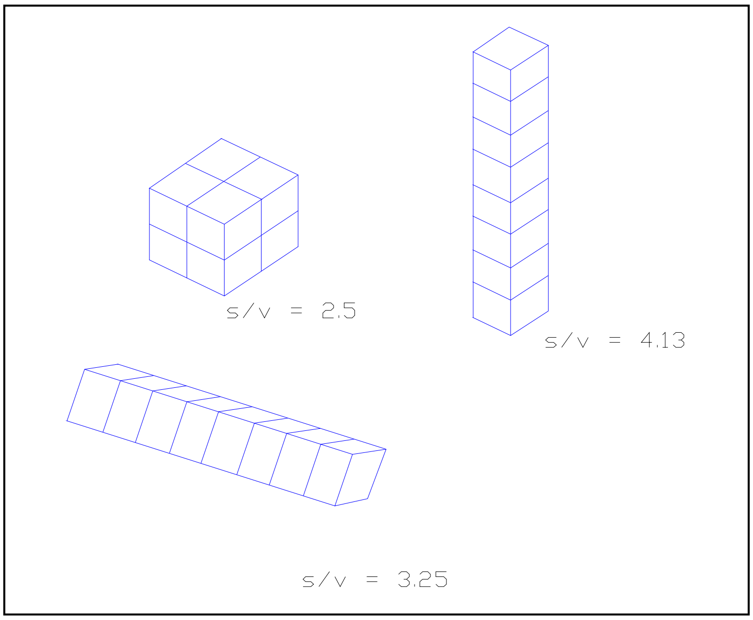


Figure (7/c): Illustration of the ratio S/V effect in shaping the urban form, an example for three ratios for the same volume, (Matteoli, 1982).

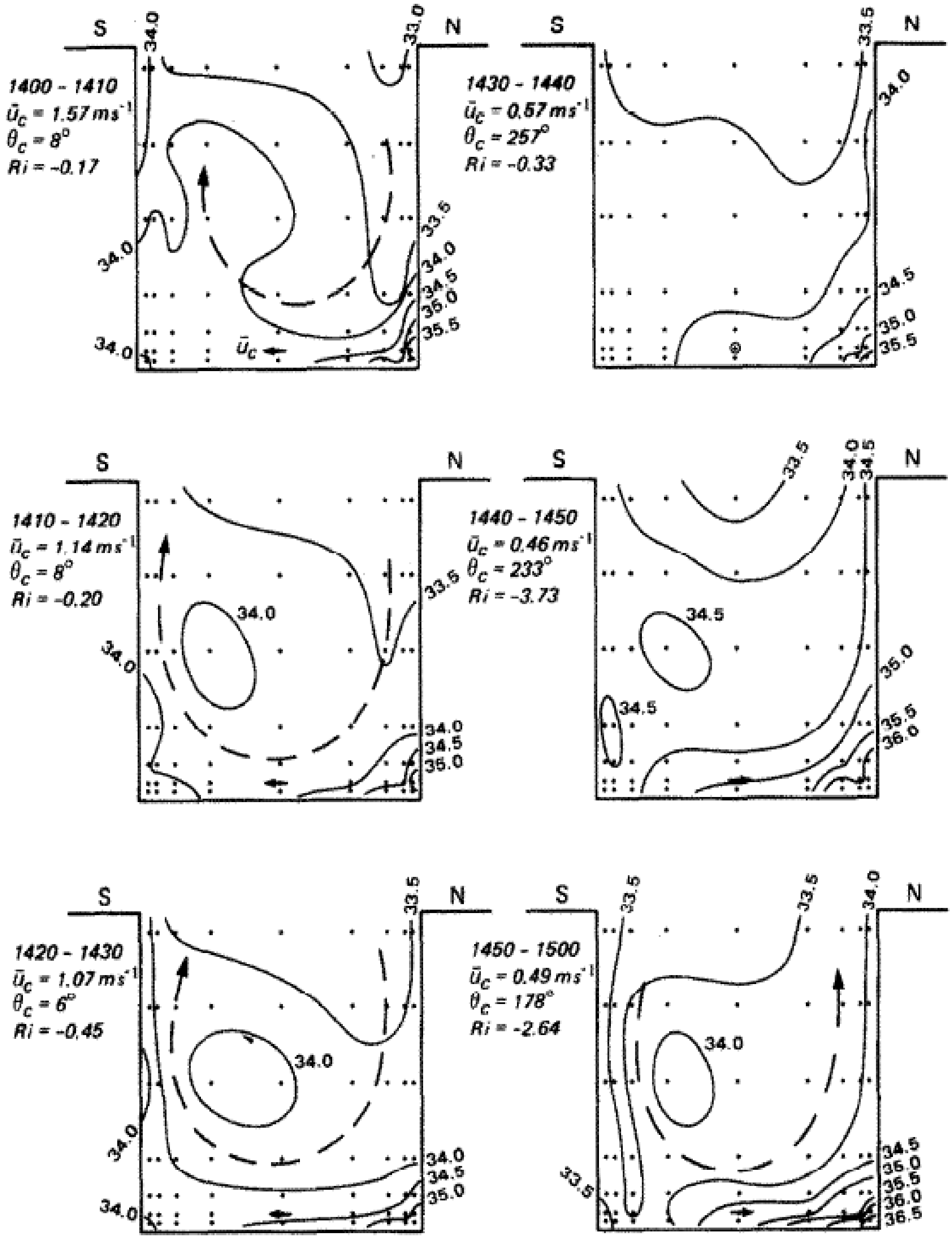
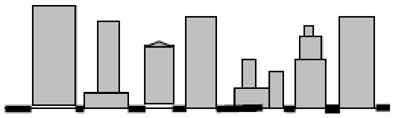
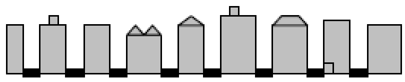
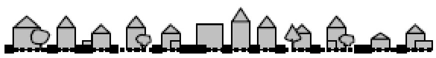
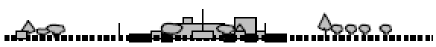
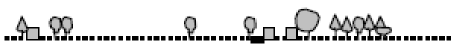


Figure (7/d): Illustration of the Kyoto's canyon of temperature – wind map, where measurements were taken from 1400-1500 in the midday with time intervals of 10 min. in 29-30 August 1984.

Many of the field researches argued that as street canyons become narrower they become increasingly isolated in term of heat exchange from upper atmosphere where studies mostly held for symmetrical geometries while micro-local climatic variations are attributable to urban spaces (canyons plus places) asymmetry and orientation have been rarely investigated, (Mills and Arnfield 1993). Some of the investigated asymmetric canyon held by (Ali-Toudert and Mayer, 2007) where details of canyon geometry, canyon SVF and roughness play a great role in modifying canyon's heat budget.

Another issue is the relations between wind directions and speed with the urban density, the effect of roughness on passive cooling by urban design and planning of local scales to generate wind breezes as one of the research concerns. (Grimond and Oke, 1999), and (Oke, 2006) have discussed those issues and classified the city urban form, figure (18/e), from the climatology application's point of view, and in fact one can observe some matching to the CNU Transect tool of urban design.

Urban Climate Zone, UCZ[1]	*Image*	*Roughness class*[2]	*Aspect ratio*[3]	*% Built (impermeable)*[4]
1. *Intensely developed urban with detached close-set high-rise buildings with cladding, e.g. downtown towers*		8	> 2	> 90
2. *Intensely developed high density urban with 2 – 5 storey, attached or very close-set buildings often of brick or stone, e.g. old city core*		7	1.0 – 2.5	> 85
3. *Highly developed, medium density urban with row or detached but close-set houses, stores & apartments e.g. urban housing*		7	0.5 – 1.5	70 - 85
4. *Highly developed, low or medium density urban with large low buildings & paved parking, e.g. shopping mall, warehouses*		5	0.05 – 0.2	70 - 95
5. *Medium development, low density suburban with 1 or 2 storey houses, e.g. suburban housing*		6	0.2 – 0.6, up to >1 with trees	35 - 65
6. *Mixed use with large buildings in open landscape, e.g. institutions such as hospital, university, airport*		5	0.1 – 0.5, depends on trees	< 40
7. *Semi-rural development, scattered houses in natural or agricultural area, e.g. farms, estates*		4	> 0.05, depends on trees	< 10

Key to image symbols: buildings; vegetation; impervious ground; pervious ground

Figure (7/e): Illustration of simplified urban climate zones arranged in deceasing order of their ability to impact local climate, (Oke, 2004), based on (Ellefsen, 1990/1991).

4- Mitigating local urban heat island effect (LUHI):

(A. J. Arnfield, 2003) has investigated and recorded UHIs research till 2003 in a historical review for urban climatology. A heat island is a phenomenon characterizing urban climate where an area of land whose ambient temperature is higher than the land surrounding it and it is produced due to the trapped heat by the built environment where UHI studies display common characteristics in which temperature difference between urban core and rural make it as a pool of warm air with largest values when closing to the urban centre and a distinction between canopy and boundary-layer UHI should be considered, (Oke, 1976), in another word “it is the difference between temperatures measured in the urban space and hose in the non-urban space surrounding it” said (Oke, 1976).

(Oke, 1981) studied the relation between the aspect ratio of urban canyon, UHI intensity and found that UHI extends in contribution to cities extensions, figure (8/a). (Landsberg and Maisel, 1972), (Balling and Brazel, 1986), (Grimmound and Oke, 2002) and (Sharon L. Harlen et al, 2006) showed that construction density, intensity of activities, urban canopy morphology and population of a city are the main reasons of the heat island effect. The UHI intensity is the temperature difference of urban core than the urban rural reserve of an urban planning community that can be measured in field along with a specific traverse or Transect which is expressed in the following equation, (Oke, 1976):

$$UHII = \Delta T_u = T_{\max} - T_{\min} \qquad (6)$$

Where; *HII* is UHI intensity.

ΔT_u is the urban difference in temperature.

$T_{\max}$ is the maximum urban temperature usually measured in urban core.

$T_{\min}$ is the minimum urban temperature usually measured in urban rural.

(Grimmound and Oke, 1999) and (Holmer and Eliasson, 1999) discussed the role of relative humidity in producing Heat Islands which is best illustrated as an interactive relation between all of the local urban climatic conditions. (Robaa, 2003) discussed the urban relative humidity intensity (URHI) which is demonstrated by the difference between the measured humidity in urban core and at rural urban areas.

The factors affecting urban humidity intensity are:

1- Surface roughness or urban texture.
2- Moisture resources.
3- Thermal performance and heat exchange of urban canopy.

$$URHI = \Delta RH_u = RH_{\max} - RH_{\min} \qquad (7)$$

Where; *URHI* is UHI intensity.

ΔRH_u is the urban difference in relative humidity.

$RH_{\max}$ is the maximum urban temperature usually measured in urban rural reserve of cities.

$RH_{\min}$ is the minimum urban temperature measured in urban core.

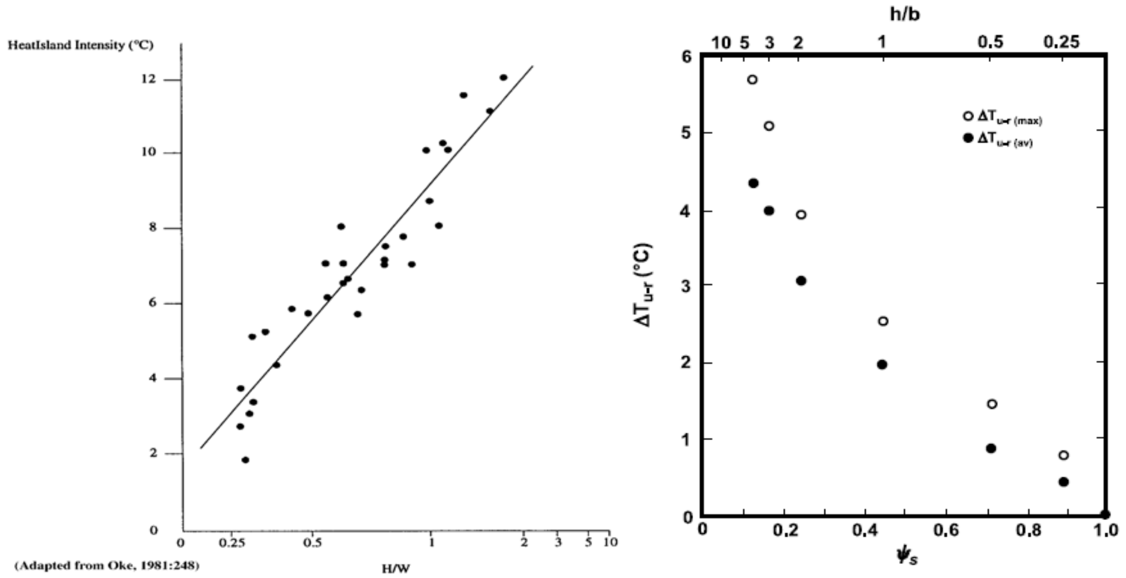


Figure (8/a): Right; Relationship between heat island intensity and H/W, left; triple relation between aspect ratio h/b, SVF and ΔT_{U-R} presented by (Kanda, 2006), both graphs for the study of (Oke, 1981).

Higher urban temperatures increase the demand for electricity for cooling and air conditioning in warm climates revealing an increase in air pollution which in turn contribute to global warming due to the greenhouse effect (Saaroni et al, 2000) and (Sofer and Potchter, 2005) hypothesized that:

1- UHI's are close to the human intensive activities, i.e. at the urban core or cities centers.
2- It is influenced by site topography and wind conditions.
3- Stronger at night or early evening due to heat emissions.

They suggested three main questions of (a) where are the UHI's are located? i.e. what is the spatial form of UHI's and research is asking also if there is an ability for many UHI's to make a UHI network regarding the production of local urban heat islands? (b) What is the time of UHI production during the day? (c) What are the main factors affecting UHI?, and the study cited a map detailing routes across Eilat and Tel-Aviv cities to monitor the climatic conditions along it. The measurement of urban structural morphological heat stresses and climatic conditions or monitoring the climatic conditions and the intensity of LUHIs which are (Voogt and Oke, 1997), (Voogt and Oke, 2003) and (Chudnovsky et al, 2004):

1- Manual or computer based and data loggers with site sensors measuring and monitoring instruments that have to be used on the street canyons and rooftop levels of the urban canopy layer (UCL).
2- Radiometers thermal photography using video cameras installed upon the highest buildings, towers, planes or choppers allover the measuring area.
3- Satellite remote sensing for thermal Photogrammetry imaging.

The complication in the second and third method that it is not specifically known what the measured temperature represents, is it the air temperature, the aerodynamic temperature near the surfaces after immediate irradiance or the mean radiant temperature that is responsible of net all wave radiation exchanges at certain time?

The answer for the question (c) is:

a- Natural aspects:

1- Topography of the site.
2- Climatology of the climatic region.
3- Season.
4- Time of the day.
5- Wind behavior, where Low effect of airflow and humidity caused by the sheltering effect of buildings which absorb heat vastly and emits it slowly, i.e. the intensity of UHI increases with decreased wind speed.
6- The intensity of UHI production increases with clear sky.

b- Physical built environment aspects:

1- Geographical location regarding site selection
2- Urban pattern type and urban canyons detailed intensity of form and construction densities.
3- Air pollution and heat production from buildings and traffic at many roads and streets that cause a siege of heat in between built form.
4- Buildings and finishing materials' physical properties that provides the thermal performance of urban canyon where surfaces absorb solar radiation during daytime and reflect heat to urban canyons that traps the emitted heat at night, (Oke et al., 1992).
5- High Population densities of urban communities and settlements delivering high automobiles numbers owning rates per community, and the increasing rates of mechanical cooling devices at certain

public canyon on some conditions of canyon spatial form encourages trapping of heat due to the heat transferred from those devices to urban canyons. "Between 2000 and 2030, the urban population in Africa and Asia is set to double." Said (PRB, 2007).

6- Non-homogenous and not designed urban pattern and canyons geometry which are mostly haven't any open spaces or scales of parks and gardens related to the planning communities' scales delivering continues heat waves in street level of urban canyon.
7- Un-designed urban planning chain of green spaces that has to be placed into urban form concludes in parse of public urban canyons' natural passive cooling applications as vegetation.
8- Changing land-usages reveal in high rates of population, pollution, cars, energy demands and consumptions …etc., i.e. anthropogenic heat fluxes, (Oke et al., 1992) and (Fan and Sailor, 2005).
9- Low individual and national income, poverty, infra declination, unsustainable developments or undoing urban developments at all, social ethnic discrimination (Sharon L. Harlen et al, 2006) and inequity of resources distribution.

By extension of urbanization, "the energy consumption for electricity, transportation, cooking, and heating are much higher in urban areas than in rural villages. For example, urban populations have many more cars than rural populations per capita. The urbanization of the world's populations will increase aggregate energy use. And the increased consumption of energy is likely to affect the environment. Urban consumption of energy creates heat islands that can change local weather patterns and weather downwind from the heat islands. The heat island phenomenon is created as cities radiate less heat back into the atmosphere than rural areas, making cities warmer than rural areas." (PRB, 2007).

The answer of question (b) is due to field measurements of the microclimate condition of a place. *It is obvious that most of these factors can be found at city centers, i.e. the urban core of a city, so that question (a) is answered but also that phenomenon can be noticed in wide non-shaded urban canyons that maximizes the thermal sensation for people in local places of urban patterns, that is what can distribute UHI over a wide land use area and in close places to form what research hypothesizing to be called Network of Local Urban Heat Islands (LUHI).*

Strategies of mitigating UHI effects are depending on studies of urban heat balance and heat circulation within canyons, (Rosenfeld et. al., 1995), (Akbari et. al., 2001) and (Sailor, 2007). Particularly, by mean of:

1- Albedo modification; Albedo is the ratio of incident to reflected radiation, (EPA, 2005).
2- Vegetation modification; increasing area, urban trees type selection…etc,
3- Combined Albedo and vegetation modification.
4- Decreasing population densities or increasing networks areas at street levels but should be studied from the Albedo point of view.
5- Increasing urban wind speed at street level.
6- Deformations for finishing materials geometry and physical properties.

5- Urban comfort:

Thermal comfort is defined by (ASHRAE-55, 1981) and (ISO-7730, 1984) as "that condition of mind which expresses satisfaction with the thermal environment". The urban comfort is about to achieve the state of equilibrium and welcoming for being in between the urban environmental content regarding physiological and psychological heat stresses. No doubt that users of urban spaces are more tolerant for wider temperature variations, plenty of clothing insulation levels, as in cold conditions they can use coats, scarves and gloves and vice versa. Consequently, users of urban spaces can adjust activity levels over a temperature range to adapt themselves for lower or higher temperatures where it is not expected to find climate conditions with in the physical comfort zone, (Evans, 2003). Conventional thermal comfort studies have had the issue from the physical thermal balance equation’s point of view as considering the environmental conditions in a steady state not in a transient one.

There are large number extensive studies, discussions and arguments have been held through the last century from the work of ASHVE Laboratory (1924-1948), (Gagge et. al., 1967), till now through many researchers, scientists and organizations whom have involved thermal comfort into their work, because of two main reasons which are:

1- All of the international standards and publications assume a fixed model of predictions based on calculating the heat exchange between human as a passive element to achieve the equilibrium with environment accounting on some inputs of the model undertaking laboratory measurements assuming European or American subjects with definite age not too old not a child, cloth insulation, fixed kinds of activities to measure subjects PMV and PPD of thermal sensation to base the energy requirements in buildings thermal design on that output data measured and standardized.
2- All of the field measurements and questionnaire studies allover the world revealed that the AMV and APD are matching the physical predictions for PMV and PPD, (Oseland, 1994), (Oseland, 1995), (Humphreys and Nicol, 2002) , (Humphreys, Nicol and raja, 2007) and (due to not only the actual subjects in the actual environment are examined but also there were a psychological factors involved in debate which has its arising voice in the last twenty years, that is the human psychological adaptation seeking to achieve thermal comfort.

we aren't here in a place to evaluate which point of view is correct and which is not, it was obvious that thermal comfort achievement must have both considerations to be studied in parallel with the urban design and planning criteria to know how urban form, pattern and spatial structure design can be optimized to serve human thermal comfort in urban spaces because theoretical thermoregulatory models are inadequate for describing urban conditions due to human mobility and the great complexity, interrelations, interactions, transiently, variability, temporally and spatiality of the urban environment.

5-1 Physical based theory for thermal comfort:

(Monteiro and Alucci, 2006) have made extensive calibration for outdoor a large number of models to investigating the suitable one for microclimatic assessment for outdoor spaces of Grande Sao Paulo, a Brazilian metropolitan area. For example Fanger has found thermal sensation of human body heat balance to be a guide in making scales for comfort depending on the PMV and PPD that are the mean value of the votes of a large group of people upon which ISO made seven point scale of thermal comfort sensation where (Givoni, 1963) made his index of thermal sensation ITS upon five scales which considers the heat exchanges, metabolism and clothes. The later has been amended by (Givoni et al., 2003) to be seven scale thermal index TS but considering the rates of sweating determined by the balance between metabolic heat production and the heat loosed by radiation and convection. A scale of seven degrees for sweating produced upon heat stress is (Givoni, 1998):

0- Forehead and body completely dry.
1- Skin clammy but moisture invisible.
2- Moisture invisible.
3- Forehead and body wet.
4- Clothing partially wet.
5- Clothing almost completely wet.
6- Clothing soaked.
7- Sweat dripping off clothing.

The perspiration heat transfer is depending on the ratio $\left(E/E_{\max} \right)$ (8)

Where; *Emax is the evaporative capacity of the air.*
E is the required evaporative cooling.

However, (ISO7730, 1994) and (B. W. Olesen and K. C. Parsons, 2002) are stating some regulations for depending on any of those indices in real design, those regulations are:

1- Validity of standards to match the real or actual thermal sensation.
2- Reliability of standards if measurements have been held many times at the same time of the year.
3- Usability of standards considering the persons whom are going to hold those measurements for thermal comfort.
4- Scope of subjects whom are the measurements held for.

Experiments had many criticisms considering the field measurements upon the criteria based from ISO 7730 itself because the PMV and PPD experiments were held in a closed chamber over a group of people in the same ethnicity and in a static environment assuming fixed area of 1.8 m2 for 70kg male and 1.6m2 for 60kg female where 1 met = 58 W/m2 and 1 clo = 0.155 m2.K/W, sedentary action on the metabolism scale that have been measured by indirect calorimetric calculations, assuming a fixed manikin model to measure the effect of thermal insulation from clothes and a sweating rate scale without considering the true dynamics properties of clothing that people wear i.e. excluding the effect of absorption, buffering, textile kind and comfort….etc.

Scale of clothing thermal insulation includes the following:

1- Naked; 0 clothing.
2- Under pants only; 0.2 clothing.
3- Short and T-shirt; 0.4 clothing.
4- Trousers and shirt; 0.6 clothing.
5- Light business suit; 1.0 clothing.
6- Business suit and thermals; 1.5 clothing.
7- Jacket and overcoat; 2.0 clothing.
8- Heavy winter gear; 2.5 clothing.
9- Arctic-type clothing; 3.0 clothing.

Those former assumptions what makes the result overestimates the design considerations and needs.

Its general equation is (ISO 8996, 1990):

$$H=M-W \quad (9)$$

And $$M+W+C+R+P=0 \quad (10)$$

Where; H *is the total metabolic heat production,*
W *is the performed mechanical work by the body,*

M is the rate of metabolic action at which body utilizes oxygen and food to produce energy is measured in w/m2 and 1 Met is 50 kcal/m2/hr = 58.15 w/m2 and is said to be the metabolic rate of a seated person at rest.

C is the convective heat exchange.

R is the radiant heat exchange.

P is the heat transferred due to perspiration.

The most promising project towards a Universal Thermal Comfort Index led by the German meteorological service sponsored by COST, ISB and WMO is trying to consider many inputs to validate the index and to make it reliable , (Hoppe, 2002), (Jendritzky and Havenith, 2005). Their equation is considering as shown down the parameters of the physical model from a general point of view:

$$M + W + Q^*_{(Tmrt,v)} + Q_{H\,(Ta,v)} + Q_{L\,(e,v)} + Q_{SW\,(e,v)} + Q_{Re\,(Ta,e)} + S = 0 \quad (11)$$

Where: M *Metabolic rate (activity)*

W *Mechanical power (kind of activity)*

Q^* *Radiation budget*

Q_H *Turbulent flux of sensible heat*

Q_L *Turbulent flux of latent heat (diffusion water vapor)*

Q_{SW} *Turbulent flux of latent heat (sweat evaporation)*

Q_{Re} *Respiratory heat flux (sensible and latent)*

S *Storage*

The meteorological data that this equation's model, UBIKLIM, depends on are air temperature Ta, water vapor pressure e, wind velocity v, mean radiant temperature Tmrt including short- and long-wave radiation exchanges considering walking speed of human as 1.1 m/s with an adaptive clothing insulation values between 0.4 and 2.6 clo and subsets of environmental parameters that included 3 different levels of ambient temperature (mean radiant temperature was set equal to air temperature), 5 different air velocities, and 50% RH in a multi node simulations can predict the human comfort state based on the PMV model, (Jendritzky and Havenith, 2005), and (Fiala et. al., 2005)

5-2 Psychological adaptation for thermal comfort:

The confusion that has been found regarding the field measurements held by many researchers for many case studies allover the world proved that the theoretical physical balance model of human thermal comfort can't been relied on when studying the human thermal (Heidari and Sharples, 2002) specially in urban spaces and more over in the arid or humid climatic regions.

The psychological adaptation is about human natural and subconscious perceptions and responses beyond the physics of the body that made in a repeated diurnal and annual normal way in harsh environment using the biological sensation to minimize the heat stress felt. 'the adaptive model reflects a give and take relationship between the environment and the user' (Brager and De Dear, 1998) and (De Dear and Brager, 1998)

The understanding that urban design and planning details supports climate sensitive planning and design has been widely spreaded in field of and realization of what can the physical elements or MPUS do for people and influence their microclimate perception is being ascending nowadays, (Eliasson et. al., 2007).

Adaptation can not be measured but just noticed and recorded because it is a human self action to improve comfort conditions and to make a reduction in thermal sensation and energy consumption. After many deep studies to define how human can adapt comfort, there are nowadays three main ways of that self control as following:

1- *Behavioral adjustments* or *physical adaptation*, that is concerning what is made by someone personality or in the built environment and is divided into three points:
   - a- Personal adjustments or reactive (Brager and De Dear, 1998) and (Marialena and Steemers, 2003) adaptation that are changing personal variables that one make like change clothing, activity, posture, eating or drinking hot or cold.
   - b- Technological or environmental adjustment or interactive environmental adaptation, which is the design considerations and modification to be done with the urban spaces' details in order to adapt a people behavior.
   - c- Cultural and social adjustments including the organizational activities, siestas and dressings of each gender.

2- *Physiological acclimatization* or *adaptation* is a human response to the repeated circumstances considering the following points:
   - a- The approved acclimatization behavior in sensory studies is more significant to be based on a group response rather than individuals, and the relative response to different environments is more significant than the absolute response.
   - b- It has been explained as an autonomic nervous system that directly affects the physiological thermoregulation set points and flow rate of blood. For example in hot arid zones the heat stress response is inducing a regime of work in heat and increasing sweating capacity for a given heat load and metabolic factor (Brager and De Dear, 1998), consequently a fall in the body's temperature set points happens to distribute body sweat. (Fiala et al, 2001) discussed the local responses of human regulatory system in terms of three equations for body shivering, skin blood flow and sweating, figure (9/a, b).

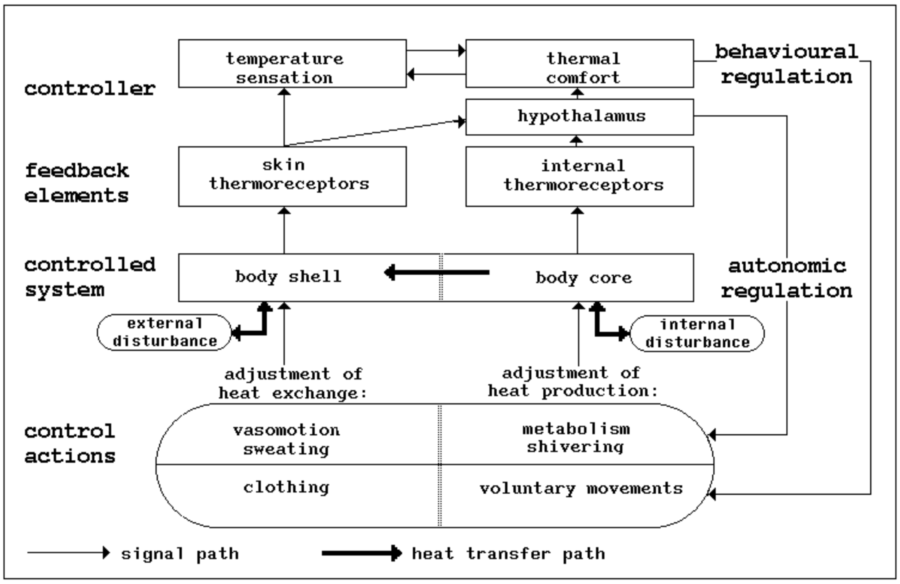


Figure (9/a): Schematic diagram of autonomic and behavioral temperature regulation in man (Hensen 1990) .

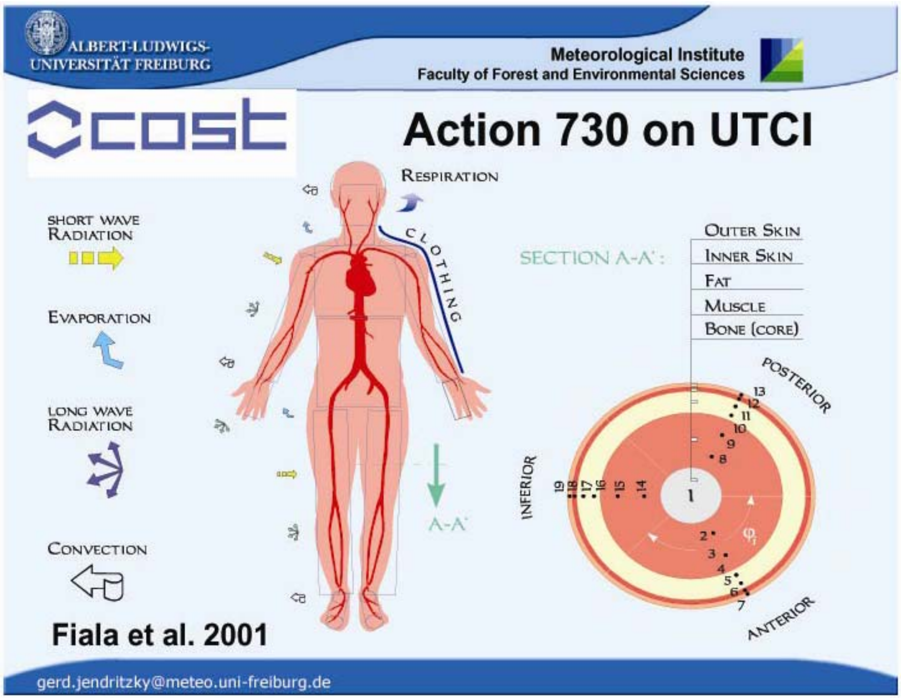


Figure (9/b): Prediction of human thermal responses of (Fiala et al, 2001).

3- *Psychological habitation* or *adaptation* implies human natural and subconscious responses in urban spaces, and that illustrates what people do in urban spaces regarding the following, (Marialena, 2003):

   a- *Naturalness;* where people can tolerate climate regarding the transiently and mobility of the outdoor conditions and the human mobility, where metabolism and clothing have a significant effect.
   b- *Expectations*; where people can predict their own model for thermal stress and take all of the precautions.
   c- *Experience;* is expressing the people short term and long term of knowledge about climate that can be explained in a term of diurnal and annual saved data about the climate.
   d- *Time of exposure;* or the time spent outdoors, herein the most reason of thermal discomfort sensation of people in hot climates. It is the spent time under the direct sun rays what increase the hot perception.
   e- *Perceived control;* is stating that people in urban spaces manage their time and reason of being in that place, sitting place in order to increase their ability of tolerating a wide range of climatic conditions.
   f- *Environmental Stimulation;* this point studies the effect of aesthetical environment and personal perceptions that should be improved by active urban design of the details and spaces what make people been attracted and adapted.

6- Urban passive cooling techniques and applications:

An urban passive cooling is the theory, methodology and practice of reducing the heat stress sensation by means of many specialization interaction and integration. The heat stress sensation lies upon human by environment circumstances due to a combination of natural heat fluxes with or without vapor pressure, human metabolism with clothing, built environment faults and psychological aspects. It is obvious from this combination that urban planner, urban designer, architect, landscaper, roads designer, comfort designer, developer, owner, user, administrator and decision maker are the paradigm of urban passive cooling methodology which is an iterating way flow chart of gathering those specializations.

The theory of urban passive cooling is the art of designing the built environment form to improving alleviative opportunities for human to adapt his local and national comfort conditions due to the control of urban pattern type and geometry of spaces, public urban canyon geometry with orientation and site slope, shading trees' scaping with its natural properties and urban infill geometry and finally, roofs green coverage and shading by roof plants.

The urban opportunities are the physical and psychological thermal perception tools used underneath a specific cooling technique as following:

1- Urban shading tools to reduce heat gain and time of exposure; urban compactness, trees and street light shading elements like arches, tents….etc. A term of urban shading performance to reduce radiant heating has to be introduced in terms of urban shaded area to its canyon's type area, i.e.

When; $Q = U.A.\Delta T$ (12)

So; $P.I = A_i / At$ (13)*

Where: A_i *is incident area of direct radiant gain at peak time of solar intensity of the maximum SVA.*

At *is the total urban canyon ground area.*

$P.I.$ *percentage of incidency is a suggested ratio for irradiance acts as a scale to identifying the capability of an urban canyon to reduce thermal sensation due to radiation by shading elements regarding the methodologies of mitigating UHI. A total passive cooling evaluation for an arid city urban planning can refer to the ratio of incident area to the total exposed area, percentage of incidency, (PI)* ***that can be considered as an item of the passive cooling evaluation for the unit urban planning of a city urban planning and smart growth.***

2- Urban ventilation for developing people expectations and perceived control; urban spaces pressure difference, linear and compact groups for wind guidance.

3- Urban evaporation for developing people expectations and perceived control; fountains for plazas, piazzas and squares, pools, lagoons and even falls for plots canyons and parks as a private urban canyons.

4- Psychological perception elements to improve naturalness, people experience and stimulate environment:

   a- Percentage of green color in the urban scene on daytime, sound comfort and cleanness of urban canyons as visual elements to decrease heart rate as physical drawback self regulatory of thermal stress, hence increasing human anti-vulnerability, stimulating environment for him or we can say giving him an urban environmental psychological vaccine that improves perceived control, figure (10/a).

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* New expression in the field.

b- Easiness of access from vehicle network plots and parking lots to urban nodes containing cooling elements which is able to be measured as the number of shaded or evaporative daytime cooling nodes to the planning community gross area, figure (10/b).

c- Population density in regard to the whole pedestrian network surface area including underground subways, i.e. the sufficiency of pedestrian networks' spaces for people in a specific land use area. On the other hand, urban structural morphology has a great impact on the pedestrian behavioral movement and flow through pedestrian network (Jiang, 1999) but it is not just movement, it depends on two factors:

1- The population density divided the allowed pedestrian area.
2- The activity attraction within the urban spaces.

Hence, a psychological and GIS study for has to account for population in regard to available pedestrian area; i.e.

$$D.P.P. = Population / A_P \qquad (14)^{*}$$

Where: *D.P.P. density of pedestrian population is a suggested scale for measuring population to the available pedestrian area at canyons street level as a reference regarding UHI mitigation methodologies. A total passive cooling evaluation for an arid city urban planning can refer to (DPP)* ***that can be considered as an item of the passive cooling evaluation for the unit urban planning of a city urban planning and smart growth***.

d- Walking distance time to amenities places that decrease the time of exposure; suggestions referring to the neighborhood, environmentalism and new urbanism such as transect, urban zoning, five minutes walk and others stimulate urban environment and perceived control.

Figure (10/ a): Green color of vegetation in a public urban scene at Paddington of London.

∗ New expression in the field.

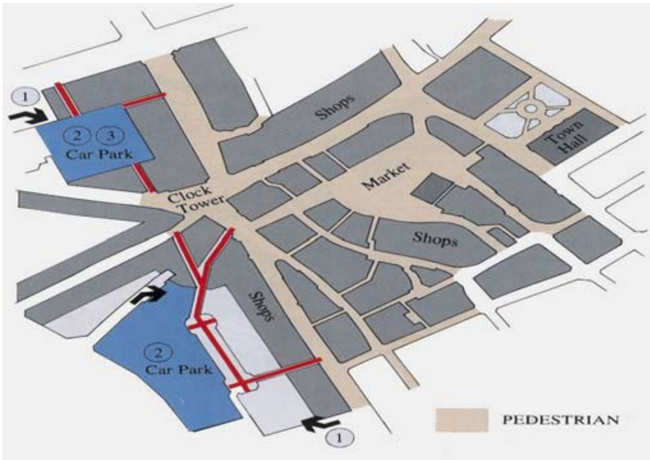


Figure (10/b): Easiness of access from vehicle network, plots and parking lots to urban nodes, Leicester, (1) are parking entries, (2) and (3) are parking lots, (Davis, 1997)

6-1 Starting from city site selection:

The local urban fine designed details that meet the requirements for outdoor thermal comfort have to be considered when establishing a community with new patterns and urban structure in order to have the optimum benefits and avoid future urban planning faults that affect the patterns in continuing its role efficiently.

Site selection has many topics to study and modern studies didn't depend only on the traditional methods of land and observatory surveying, but also on the GIS for over ground and underground geo-technical and environmental evaluations of site selection and land use planning. Those factors are:

1- Natural resources of water, minerals, building materials, tourist places, beaches and rivers, heritage places and antiquities.
2- Feasibility of international, national, regional, and local connection and intersections of various types of transportation networks.
3- Feasibility of connecting new communities with the exist networks of sewage, drainage.
4- Environmental impact assessment for the natural ecological life.
5- The relation of the site to the national and international ring of earthquakes and volcanoes.
6- Climatic data survey.
7- Topography and leveling details of the site those suites specific zoning from land-use concept alternatives that decide the tendency of the community towards a specific activity (i.e. industrial, agricultural, recreational…..etc) and their networks, infra, construction regulations of that zone buildings.
8- Urban planning growth of an already exist community patterns.

6-2 Choosing an urban pattern type:

The expression urban pattern is used to define the final form of urban planning tissues due to the same meaning of intersections, interactions and interdisciplinary correlations where the lines and intersections of that tissue forms the networks, circuses, squares, places, canyons and urban objectives of the urban pattern, (Soliman, 2002) and (Fahmy, 2007).

Urban pattern gives an impression for the urban spaces, places and canyons that is formed due to the pattern type. Pattern types can be classified in reference to a couple of aspects:

1- Shape of networks: it have four main network types that can be classified into other sub-types, the four main types are:
    d- Grid type, figure (11/a, b, c).
        - Normal grid.

   - Branched grid.

e- Hierarchy type which can be, figure (12/a, b, c):
   - Diagonal.
   - Radial.
   - With long routes.

f- Organic type, figure (13).

g- Mixed type, figure (14).

2- Shape of fabric: it refers to the fabric shape and it could be any of the previous classification also, i.e. dot grid pattern or linear organic pattern …….. etc:

a- Dot shape pattern, (15).

b- Linear shape pattern, (16).

c- Compact shape pattern, (17).

Figure (11/a): Branched grid pattern shape at Nasser City, Cairo, Egypt.

Figure (11/b): Normal and branched grid pattern shape at Nasser City, Cairo, Egypt.

Figure (11/c): Normal grid pattern, Riyadh, Saudi Arabia.

Figure (12/a): Hierarchy diagonal pattern, Tunis the capital, Tunis.

Figure (12/b): Hierarchy radial pattern, Misr Al-gadida, Cairo, Egypt.

Figure (12/c): Hierarchy with long route pattern, Heritage Cairo, Egypt.

Figure (13): Organic pattern, Rade burn, Fair Lawn, New Jersey, USA.

Figure (14): Mixed pattern, Al-Mohandseen, Cairo, Egypt.

Figure (15): Dot branched grid pattern beside the Military Academy stadium, Cairo, Egypt.

Figure (16): Linear branched grid for multi family housing pattern, Al-Fangary road, Cairo.

Figure (17): Compact grid with route pattern around the Holy Mosque, Mecca, Saudi Arabia.

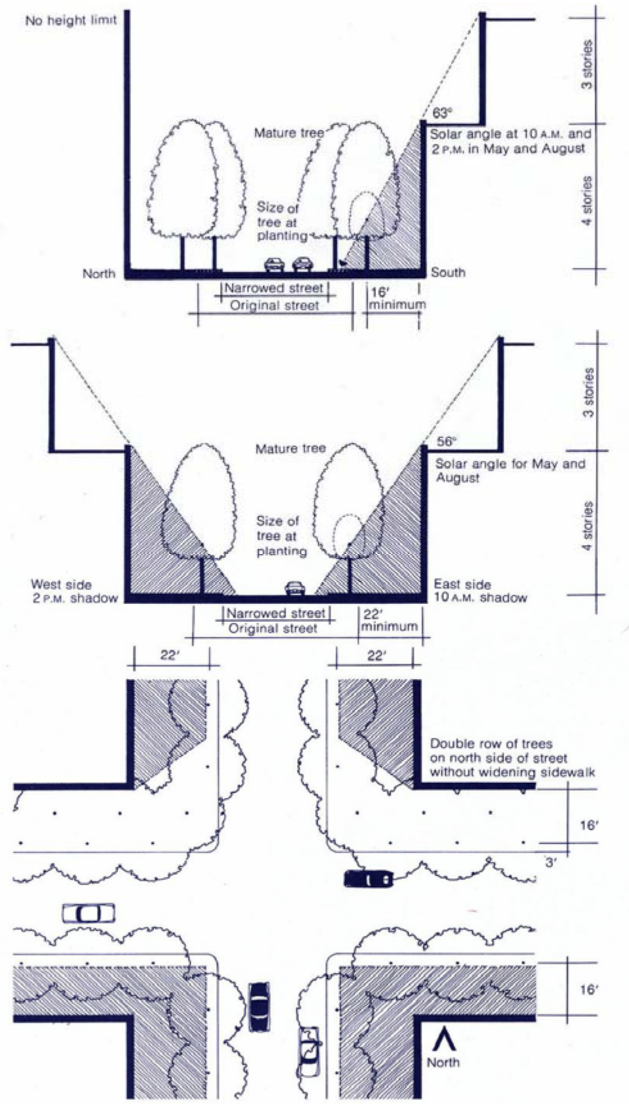


Figure (18): Example of building block orientation with groups of urban trees to provide advanced urban canyon shading, (Arnold, 1980)

Proceedings of the 7th ICCAE Conf. 27 -29 May, 2008

6-4 Potential to having urban green cooling nodes:

Although all of the urban planning theories are citing and stating that each urban planning community has to have its public green and vegetated land use area, because "parks and green areas are known to create park cool islands (PCI)" said, (Saaroni and Ziv, 2003), same meaning said (Givoni, 1998), (Spronken-Smith and Oke, 1998) found that PCI intensity could be 3-5° C in Sacramento and (Spronken-Smith and Oke, 1999) investigated diurnal PCI where wittedness is essential after sunset to daytime PCI to take effect while dimensions of the park have to be 2.2-3.5 the height of the border trees at minimum, (Chudnovsky et al, 2004), (Waziry, 2004) argued for same, where cooling effect from shading decreases the energy demand for mechanical cooling at day time and stimulates nocturnal cooling effect and long wave radiation depending on the sky view factor SVF and the open area exposed to open air, as SVF increases radiant cooling effect increases (Rosenfeld et. al., 1995) specially at residential areas (Huang, Akbari, Taha and Rosenfeld, 1987), to generate cooling breezes from parks to the near fabric (Eliasson and Upmanis, 2000), to improve air quality, (Akbari et. al., 2001), and (Murakami, 2006) demonstrated that parks and vegetation have a magnificent role in increasing health quality, thermal stress reductions and aesthetic benefits. (Lam, et al, 2005) found that parks and open spaces in Hong Kong have their effect in reducing the noise effect and increasing air quality and (Gidlof-Gunnarsson and Ohrstrom, 2007) found in a questionnaire analysis the potential of noise reduction while increasing quality of life near green spaces.

Scales of parks and gardens are related to the planning communities' scales, (Oke, 1989), i.e. city has to have its park/s, Town has to have its park/s, Community/district has to have its park/s, neighborhood/village has to have its garden/s, each group of buildings blocks has to have its garden /s and each block or single building has to have its garden/s, figure (19/a, b) which introduces a shape of cooling nodes network allover the urban planning community. Values of Urban parks are many:

1- It provides urban spaces and canyon types with ordered modules.
2- Cleans environment and upgrade air quality.
3- Acts as wind barriers regarding the kid of trees used.
4- It is an important element for shading, direct gain diffusion, evaporative and nocturnal cooling. In total as cooling node.
5- Stimulates the environment for human psychological adaptation.

A total passive cooling evaluation for an arid city urban planning can refer to that as green equity distribution on the transect tool (Greensect) * ***that can be considered as an item of the passive cooling evaluation for the unit urban planning of a city urban planning and smart growth***.

* New expression in field.

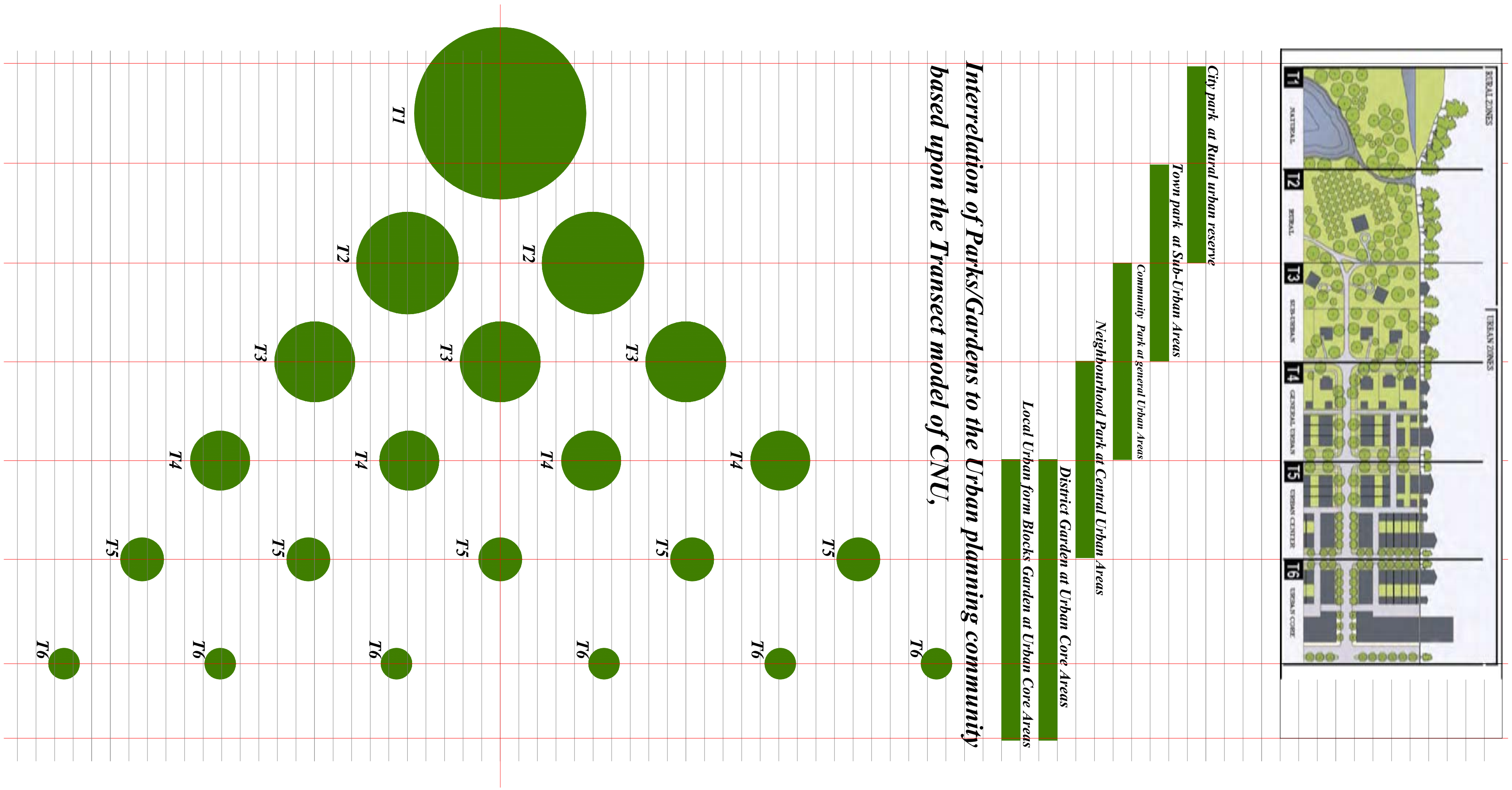


Figure (19/a): Suggested Urban Parks/Gardens cooling network of green islands mitigating LUHI network called as ***Urban Greensect*** regarding its geometry over a city Transect, i.e. each urban planning level on the transect of a town/city has to have its hierarchy of greensect, where distances to:

1- Less than 5 min walk due to about 4km/h walking speed (Jendritzky and Nubler, 1981), (Jiang, 1999) and (Duany, 2002) should be for cluster garden
2- Same neighborhood/village level public green area can be set to 70-200 meters of about 5-15min walk for the same previous criteria.
3- Whole urban planning suburb or district or to up of one urban planning level public green area can be set to 200-900 meters walking, i.e. regardless (Barbosa et al., 2007) has mentioned from 300 meters for same level, it should be adjusted to 5-15 min walk.

Proceedings of the **7th ICCAE** Conf. 27 -29 May, 2008

4- Small town/community level public green area; double to the previous level, i.e. about 2000 meters, i.e. in about 30 min that shouldn't be walked after this level.
5- Town level public park area; up to double to the previous level of 5000 meters.
6- City level Public Park double to the previous level of 10000 meters.
7- Capital or regional park level up to double to the previous level of 20000 meters.

Left; Figure (19/ b): Each urban planning level has to have its efficient park/garden area which is continued as a chain from the urban core to urban cluster level, Karlsruhe, Germany.

6-5 Minor urban cooling nods:

It is meant that a small cooling node within a single building block (not a single building) can provide a local cooling for that block which can be considered as the minor unit of the urban cooling pattern allover the urban planning pattern. (Givoni, 1998) citied that attached open spaces, enclosed or semi enclosed, patios and internal courtyards enhance the interactions between indoor and outdoor *(which is called positive negative spaces and could be due to the design details of buildings blocks in contact to a local urban space).* Those minor cooling nodes are the roof garden and the block's court yard; figure (20/a):

1- *Roof garden*: It is a roof of building that is partially or completely covered with vegetation and soil, or a growing medium, planted over a waterproofing membrane:
   a- Thermal insulation for buildings.
   b- Evaporative cooling effect.
   c- An increased percentage of overall city greenery coverage that reduces Albedo of heat exchange catalyst and absorbent surface finishing materials.
2- *Court yard and back yard*: is an area of the private urban canyon in buildings plots at in the back yard of group of a single building or a group of buildings, this element specially has a magnificent cooling criteria due to the pressure difference and the relation between its geometry proportions length, width and height that stimulates the air movement rather than a dotted pattern buildings, even (Aldawoud and Clark, 2008) found that the open courtyard building shows a better energy performance for low rise buildings depending on the architecture of the courtyard facades.

   (Waziry, 2004) found that the optimum proportions for courts in the arid Toshky of Upper Egypt at 22 degree latitude are (W:1-L:2-H:1.40) or (W:1-L:2.50-H:1.58) or (W:1-L:3-H:1.73) when fixing the volume and enclosure ratio is slightly modified if the longitudinal axes is oriented to the north, figure (20/b), *the aspect ratio (Width, length, height) or enclosure of a block of buildings is used to modify the urban form that is optimized with orientation to give the minimum heat gain in peak hot times of summer and the maximum heat gain in peak cold times of winter.*
3- *Groups of urban trees:* this expression is referring to the trees arranged in specific order to affect the urban canyons microclimates. Those arrangements can be defined as patterns are defined, *i.e. it can have the shape of dots, lines or compact groups to help affecting climate conditions and delivers a valuable surface shadowing area for the planning community, it can be called city trees pattern (CTP) which may be apart of the city Greensect or not, i.e. the Greensect consists of all types of city vegetation either it is a park/garden or only a tree coverage.*

Proceedings of the 7th **ICCAE** Conf. 27 -29 May, 2008

Figure (20/a): A combined array of green roof with a remarkable block back yard with roof garden affect the local urban climate and break the heat islands chain regarding the canyon geometry, canyon trees, slope with orientation and housing types.

Figure (20/ b): Linear shape of urban trees, Upper Hanover Street, Sheffield, UK.

6-5-1 Urban Trees usage, scaping and planting time:

The need for urban trees integrated within the fabric is no doubtable as vegetation element, (Rosenfeld et. al., 1995), (DOE, 1995), (Givoni, 1998), (Eliasson and Upmanis, 2000), (Chudnovsky et al, 2004), and (Waziry, 2004). (Matsuoka and Kaplan, 2008) discussed people needs in landscape and found that they need contact with nature, aesthetic preference, recreation and play, (Huang, Akbari, Taha, Rosenfeld, 1987) modeled the summer cooling effect of trees in some American cities and found that huge reduction in mechanical cooling demands can be achieved by trees’ shading and the reduction maximized upon increase in trees coverage specially if applied on an urban scale where wind can show reductions in speed due to canopy density not the canopy height, it can be concluded from this point that selection of special tree kinds can provide maximum shading because of canopy height rather than the canopy radius at specific year time, figure (21/a), (Kotzen, 2003), while accurate selection of a the same tree canopy density shouldn’t decrease canyons wind speed.

However, usage and benefits of urban trees can be summarized as following:

1- Physical effects in modifying climatic circumstances by shadowing generation and minimizing SVF, figure (21/b, c, d) that directly affect the net all wave radiation and canyons energy balance and evapotranspiration contributing to the redistribution of urban spatial water vapor, total urban spaces Albedo, hence mitigation of cities UHI and neighborhoods LUHIs, (Huang et al., 2008) As a conclusion, urban trees physically participate in urban passive cooling.
2- It has great role in making visual perspective, for example it provide the 33.33% of the supposed upper part or the green ceiling of canyons to

stimulate urban spaces for psychological adaptation. Urban spaces and places spatial format, order, harmony, contrast, scale, proportions and variety can be contributed to trees urban arrangements, figure (21/e).

3- Filtering environment from Carbon dioxide, dusty sand, regenerate oxygen and improve health, (Akbari, 2002).
4- Reduce noise levels, (Lam, et al, 2005) and (Gidlof-Gunnarsson, Ohrstrom, 2007).
5- Provide confidentiality especially for residential land uses and buildings, (Bentley, Alcock, Murrain, McGlynn and Smith, 1985).
6- Help in reducing energy demands especially in residential areas as an element vegetation, (Kum, Bretz, Huang, and Akbari, 1994), (DOE, 1995), and (Taha, 1997).

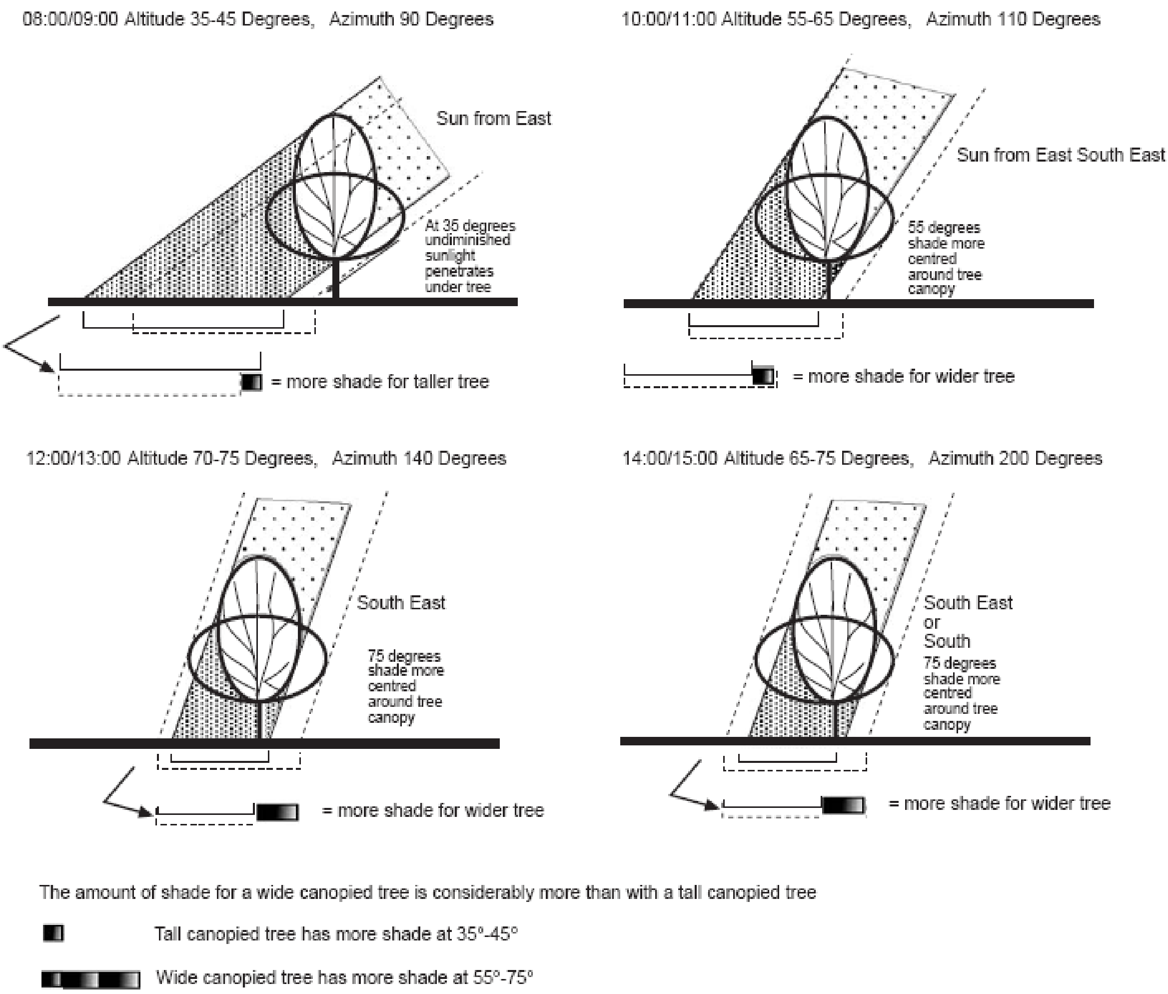


Figure (21/a): Comparison of the amount shade created by broad/wide canopied trees in contrast to tall canopied trees (Kotzen, 2003).

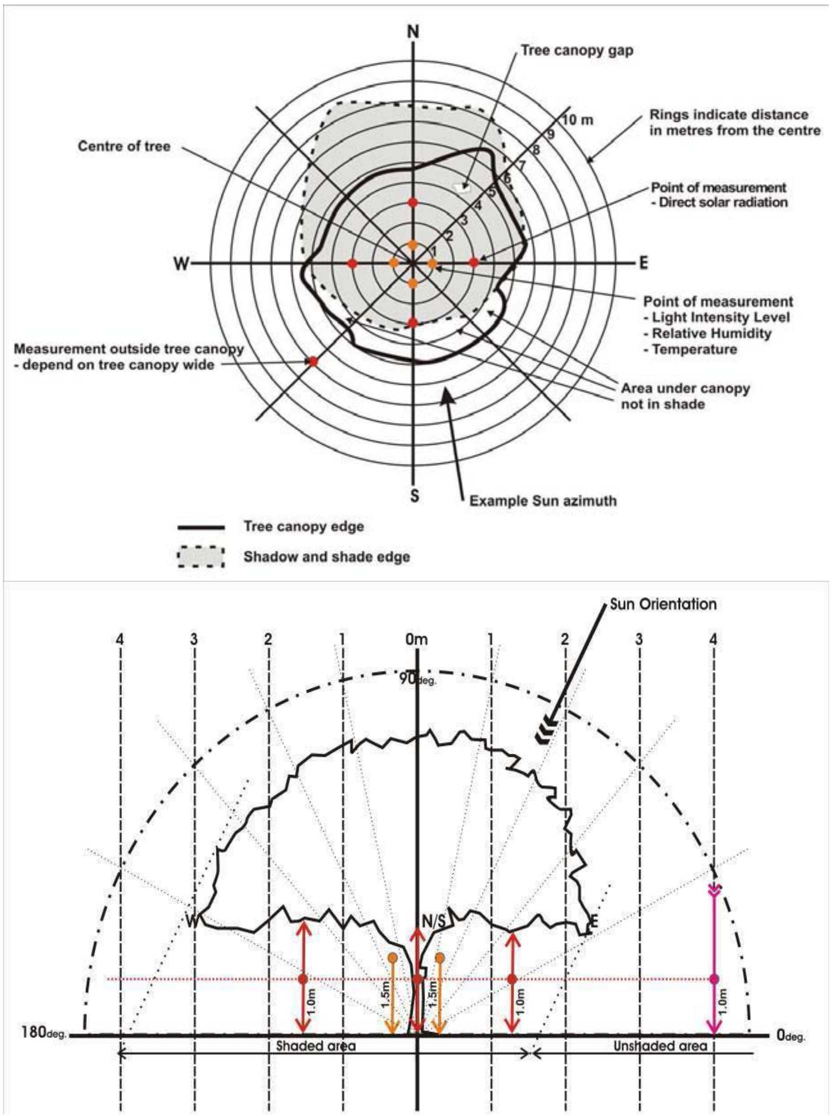
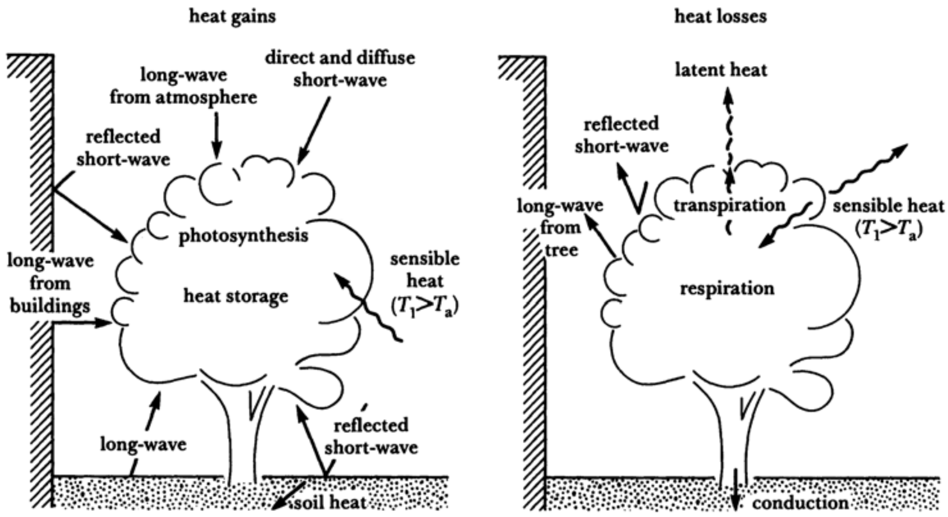


Figure (21/b, c): a; Urban trees shading produced on the sun azimuth protractor and b; tree geometry affect micro climate, (Shahidan, Salleh, and Mustafa, 2007).



Scheme of the daytime energy exchanges between an isolated tree and its street canyon environment. (T_1, T_a, temperatures of leaf and air.)

Figure (21/d): thermal behavior of trees, (Oke, 1989).

Figure (21/e): Aesthetic values of urban trees.

Urban trees scaping depends on the site configurations that directs and decide the plantation places, kind of trees, time of planting where urban planning has to have earlier decisions concerning plantation for urban trees to achieve their mature age at the same time for the patterns and, figure (22), (Arnold, 1993) and (Trowbridge and Bassuk, 2004).

The kind of urban tree is decided upon the function it will be used in, i.e. would it be for shading, wind barrier, urban decoration, urban place making and way finding, or else. This function will orient the configuration needed in such a tree kind.

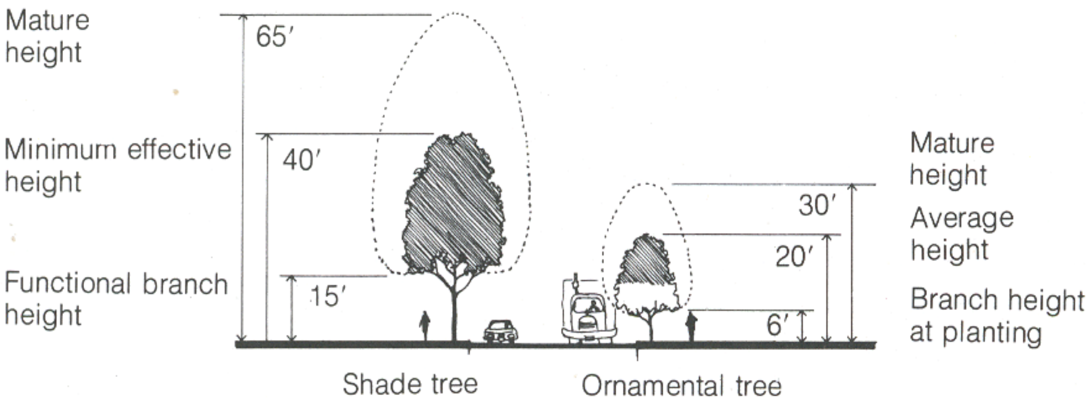


Figure (22): design of mature tree geometry, (Arnold, 1993).

6-5-2 Trees geometric and thermal characteristics:

The geometric characteristics of trees depend on the urban site the mature structure of a certain type tree; figure (23). However, urban tree can be described geometrically by:

1- Total mature height.
2- Mature canopy radius.
3- Mature canopy height.

While those geometrical descriptions contribute to thermal characteristics depend on another important botanical factors such as:

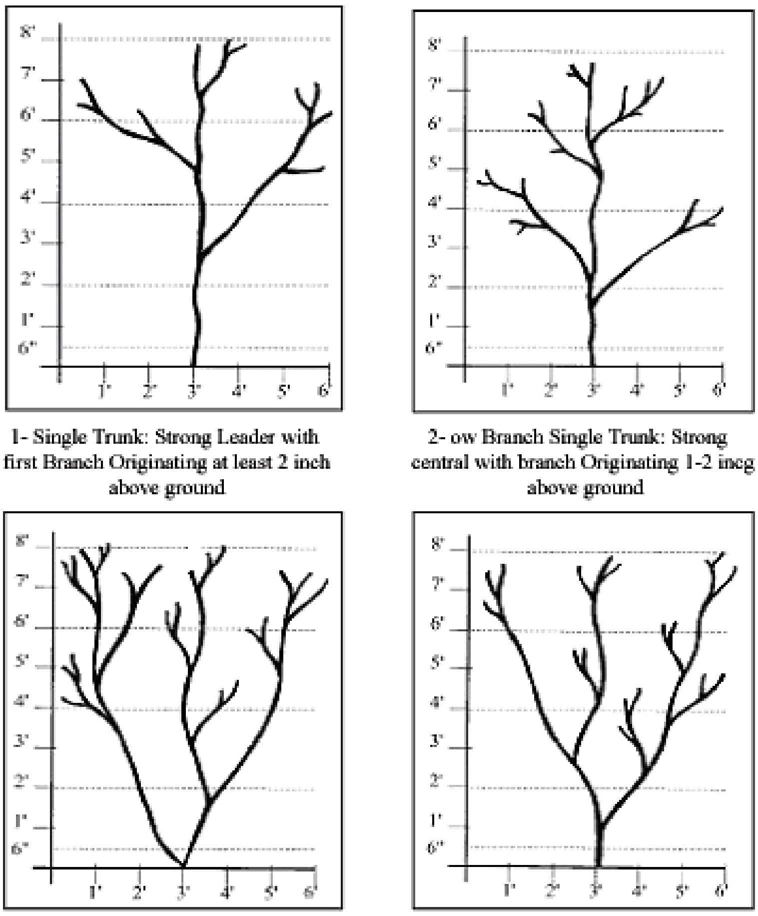
1- The leaf area density of a tree.
2- Deciduous or evergreen.
3- Capability to bear harsh climates; cold or hot.

Other botanical characteristics such as:

1- Kind of soil to be planted in.

2- Depth and radius of roots.
3- Capability of bearing site hazards and emissions.

Tree Structures



1- Single Trunk: Strong Leader with first Branch Originating at least 2 inch above ground

2- ow Branch Single Trunk: Strong central with branch Originating 1-2 incg above ground

3- Multible Trunk: a) climp tree with 2 or more trunk origintaing from ground or not more than 6 inch above ground b) Shrub form tree with multible trunk originating from ground.

4- Low Breaking Multiple Trunk: First Branch Originating Between 6-18 inch

Figure (23): Different shapes of trees structures,
Adopted from (www.aridzonetrees.com, Accessed January 2007).

Tree thermal behavior can be understood from figure (21/d) as direct sun beam hits the ground around a tree, ground temperature increases and later on the air temperature increase by emitting long wave radiation along with convicted short wave, because of shade under trees the equation represents heating balance of net all wave radiation, heat stored, sensible heat near ground by convection (Levinson, 1997), latent heat is achieved but with less magnitudes on both sides of the equation due to canopy prevention of short and long wave radiation from the upper hemisphere to reach the ground. That is why people prefer places under trees and how can shades contribute to less heat budgets and cooling, unless certain circumstances happen like low wind speeds, higher values of H/W of a street canyon…etc.

Cooling is maximized due to the evapotranspiration effect of a tree, that can be contributed to its water vapor carrying capacity whilst wind speed is catalyzing evaporation that is considered evaporative cooling of the tree surrounding air, (Kurn, Bretz, Huang, and Akbari, 1994) and (Dimoudi and Nikolopoulou, 2003), i. e. less heating rate for that surrounding air. Thus, compositions of urban tree's canopies can help in closing to urban passive cooling both in micro and local scale.

Evapotranspiration of a plant can be calculated from (Kurn, Bretz, Huang, and Akbari, 1994):

$$ET_c = K_c \times ET_0 \qquad (15)$$

where;

ET_c is the evapotranspiration of a crop c.

K_c is the crop coefficient.

ET_0 is the potential evapotranspiration of vegetation derived in terms of air temperature from the regression equation of (Jensen and Haise, 1963) :

$$ET_0 = (0.0252T_a - 0.078).(1-a).I \qquad (16)$$

where;

I is the incident solar radiation upon crop.

a is the crop or vegetation Albedo.

7- Conclusions;

a- Complexity in the field of urban climatology prevents the application of knowledge to the urban realm for a better designed urban planning patterns that delivers physiological and psychological comfort.

b- Complexity is revealed from the interdisciplinary correlated subjects and specializations, such as;

1- Heat transfer physics.
2- Human thermal regulatory aspects.
3- Urban planning and design methodologies, trends, statistics, growth control, fabric and urban space principles with place making and spatial theory.
4- Urban landscaping and TreeScaping.
5- Total environmental policy and life style quality.
6- Meteorological data analysis.
7- Remote sensing for thermal imagery.
8- Field measurements, instrumentation and installation concerning different urban climate levels.
9- Tools, techniques and applications of passive urban design and control.
10- Improvements in real environment simulation computer packages.

c- Urban passive design is not to close to human thermal comfort in urban spaces and places or only to reduce energy consumption by about 40% in residential patterns as some researches tells, but also for a complete well designed urban life.

d- A passive cooling system provided with techniques and applications can be introduced to the urban pattern and form both in its design scheme, design process and execution of the physical fabric of urban planning community to enable the fabric product to generate, adapt comfort or even alleviate outdoor thermal stresses for people where special passive tools for patterns and form design in hot climates should be used along with conventional responsive urban fabric to have correct urban planning and design decision.

Proceedings of the 7th ICCAE Conf. 27 -29 May, 2008

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