Robert Samuels 1998

Millennium Paradigms: Habitability and *fin de siecle* Urban Climate

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Introduction: Livability and the Urban Thermal Experience

The ubiquitous thermally-polluted city and urban thermo-genic (heat-generating) lifestyles are emergent phenomena of the 20th century. The thermal impact of the urban climate on comfort, amenity and health is the focus of this paper - one in a series evaluating sustainability and habitability potentials for 21st Century urban environments.[1]

At the turn of the millennium, *fin de siecle* awareness amongst urban ecologists seems to be centred on energy and environment relationships – on greenhouse gas or $CO_{2\text{-equivalent}}$ emissions consequent on the burning of fossil fuels. However vital this link, it is *heat* which is the essential, active component of climate change; the importance of the greenhouse gases being, thus, their *heat absorbing* capacity. Mitigation of urban heat generation is no less essential than controlling energy use. Cities use 'infinite' amounts of energy and, so doing, generate unimaginable mega-therms of heat. Even the consumption of 'cool' renewable energy inevitably results in the production of waste heat, which is deposited in the urban atmosphere, impacting on both urban climate and global climate. The relationship between urban heat and $CO_{2\text{-e}}$ emissions is synergistic and synchronous – arising from thermo-genic urban lifestyles, locked together they rise from the urban mass to the greenhouse mantle.

Urban form and street geometry are factors fundamental to the amelioration of this toxic embrace, as is urban greening.

The climate imposes massively on the lives of thousands of millions of people. In hot humid countries, such as those between the Tropics of Cancer and Capricorn, the addition of urban heat islands and global warming to this already stressful setting gives the cities of this geo-climate a special place in the research on urban thermal experience – irrespective of the varying influences of cosmology, culture or colonialism on their particular urban forms. It might be argued that people in cold climates would appreciate a warmer world, and agricultural production could be enhanced, but these are superficial and short-sighted advantages since bio-diverse eco-systems evolve slowly over time and cannot adapt to rapid change.

To this research is brought the view that embedded in the urban nature of old cities - Scandinavian, European, Islamic or Asian - despite their differing climatic and socio-cultural realities, is a generic, organic streetform and builtform which embodies millennium–old notions of habitability and sustainability, as valid in the 21st as the

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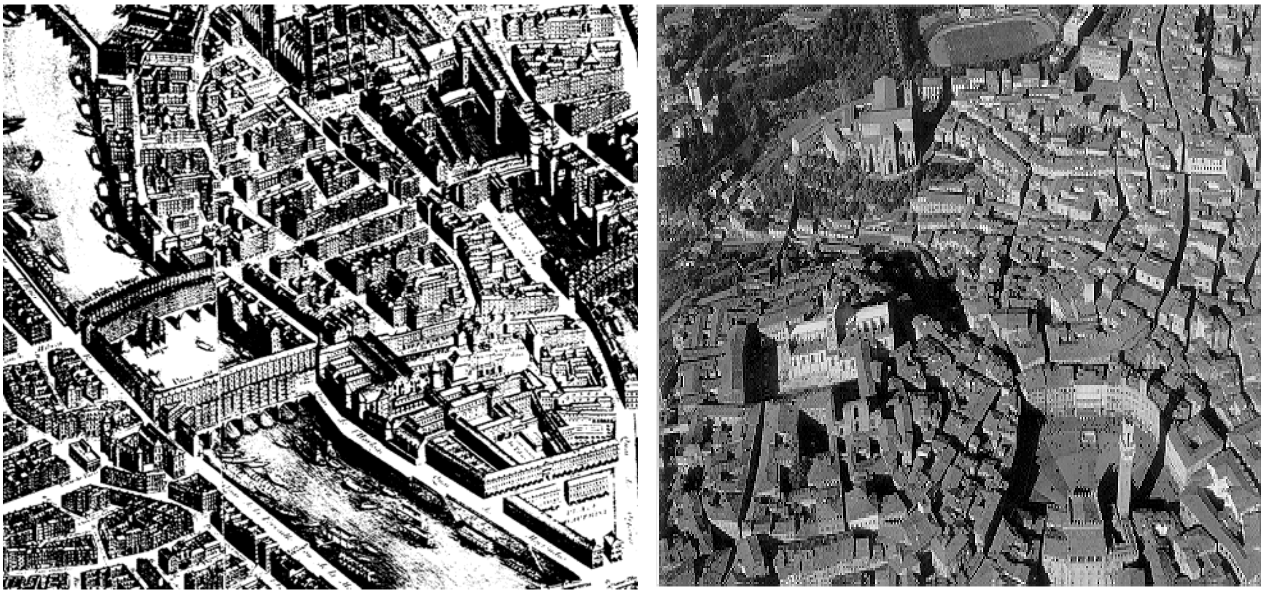
[1] see: Samuels (1998), *Urban Climate and Thermal Pollution: Sustainability and Habitability in Urban Environments*, First International Conference on Quality of Life in Cities, Singapore…which considered the relationship between urban climate and global climate.

12th century. It is necessary to take a detached view of the old city in this conceptual model; not dwell on the feudal inequities, gruesome plagues and rampant tuberculosis nor the dark, dank alleys and buildings, but reflect on the climatic congruency of the organic urban form, the living street, the architectural integrity and sheer beauty of the walled, hill-city, and the 'socio-spatial' coherence – the *in-built* opportunity for community identification and interaction *and* individuality, and especially the palpable sense of place emergent at the human scale (walking is human motion supreme; cycling a quantum leap). Modern technology can largely overcome the primitive health and amenity compromising aspects of cities of old; but not



completely, witness the prevalence of tuberculosis today, even in the most 'modern' of western cities.

Pedestrian Cities: 15th century Paris: almost unchanged today; Siena, ancient *and* modern city (Sources: Rudofsky, 1969, *Streets for People*; and Riproduzione Vietata)

Urban thermal pollution can be traced to a few powerful factors, amongst which are: thermal embodiment in the urban mass (the heat island effect), incidental heat emissions (thermo-genic urban lifestyles), hot energy generation (combustion), and the exclusion of natural evaporative coolers (trees) and heat sinks (water) *ie* of cool islands. Exacerbating factors are poor urban design, which ignores the ingenious geometry of ancestral urban shadowing and ventilation configurations, urbanised populations seduced by 'car-friendly' orthogonal street grids, and by hi-rise corporate-image, climate-rejecting, air-conditioned CBDs and high-density residential tower complexes - where the 'urban canyon' effect distorts both air circulation patterns and traps solar radiation.

Urban Climate and Thermal Experience

Heat Stress and Thermal Discomfort

The same variables that influence thermal comfort in buildings apply at the urban scale, but here age is particularly relevant, with the elderly being significantly more vulnerable; heat-related death rates (per 100,000 population) cited for a standard western urban population varying from 0.5 in children up to age 4 to over 14 for people aged 75 or more. Heat stroke kills about 4,000 people in the US during an average year (www.tdh.texas.gov).

Less dramatic is the thermal discomfort experienced in hot, humid, unshaded cities, which can, nonetheless, significantly impact on quality of life, albeit not recorded in epidemiological statistics. State of mind is no less relevant as an indicator; and it has long been appreciated that aggressive behaviour such as street offences and urban riots increase during hot weather; contemporary studies in both the USA and Australia again confirm this (www.BoM.Australia). Recently, a Heat Stress Index has been developed, measuring how hot it ‘feels’. Sensible heat is significantly influenced by urbanisation: impervious surfaces limit evaporative cooling, heat is stored in the urban mass, and albedo reflections bounce around urban canyons, all resulting in a diminished heat exchange capacity in cities, and hence an increase in thermal discomfort (Oke, 1982). Further, night-sky flushing – a principal factor in climate-responsive, naturally air-cooled buildings and cities – is compromised by a diminished heat exchange differential when nights are warmer than previously: a symptom of both urban warming and global climate change.

Thermal Pollution, Air Pollution and Health

On a warm summer day evaporative emissions of volatile organic compounds (VOCs) from motor vehicles are about three times higher than on an average winter day. Even more crucial is the capacity of both sunlight and temperature to control the degree to which pollutants such as NO_x and VOCs react to form photochemical urban smog (ozone). A 3^oF drop in temperature in a major heat island like Los Angeles cuts smog by 10 percent; and the probability of smog increases by 5% for every 0.5^oF rise in temperature (www.LBL.gov).

Ozone-smog (it is claimed) is partly responsible for the observed increase in respiratory, cardiovascular and cancerous diseases in large tropical cities (Jauregui, 1990). Acute respiratory infection results in about 4 million deaths worldwide in a given year, with about 250 million new cases (from all causes) being reported annually (Platt, 1996).

Urban Impact of Climate Disruption

It is difficult to accept that the flooding rivers, cyclones and tornadoes, drought-induced forest fires and peri-urban fires witnessed more and more frequently in the recent past are not exceptional, thus anthropogenic to a discernible extent, even if overtly caused by El Nino oscillations - since these too are occurring exceptionally. Logically, should we not expect there to be a link between warming water in the Pacific Ocean – the trigger – and global warming?

The impact of climatic extremes on urban populations is already substantial; by the year 2000 the UN estimates that some 50% of the earth’s population will be urbanised (up from only 10% in 1900) – yet another unique 20^{th} century circumstance. Simultaneously with this migration from rural regions is an urban *eco-refugee* phenomenon, where huge populations can be displaced in the wake of aberrant weather events; and the world has yet to experience the full reality of coastal settlements in low-lying lands such as Bangladesh, or the Pacific Islands, or the Netherlands threatened by swollen oceans lashed by violent storms.

Urban Form and Habitable Urban Climates

Mixed-Use Urban Zones

Separation of land-uses automatically involves travel, apparently suiting the motorised-vehicle based 20th century city, but slowly strangling the life out of it. Irrespective of the extent to which the urban road and freeway system is expanded, it inevitably becomes grid-locked; and urban air pollution is an endemic consequence. Old cities, however, were compact and contiguous, with a multitude of activities coinciding in space. The old-city of Delhi, for instance, has narrow lanes with mixed land-uses - not dissimilar to medieval European and Islamic North African cities. Many modern cities still incorporate this rational, integrated land-use approach, Paris one outstanding example.

> The decentralised nature of the organic city prevented needless circulation - it kept the whole town in scale (Mumford, 1961/91)

> All streets within the medieval town were markets of some kind (Saalman, 1968)

From yet another perspective, a mixed-use urban domain with a dense network of streets naturally populates an area, bringing 'eyes onto the street' (Jacobs, 1961), and results in heightened animation and surveillability opportunities, especially 'afterdark' (Samuels, forthcoming). Such an old city/new neighbourhood paradigm can naturally accommodate both the organic, narrow and curved street *and* sightline requirements for security via the integrated urban square which, in the jargon of situational deterrence, might be called a 'sightline node' - where movement paths intersect and lines-of-sight change direction (Samuels, 1995). If the 'space syntax' of such nodal points is convex in shape (Hillier & Hanson, 1984), anyone entering the area can see everyone else there.

Copenhagen Urban Square: animation, visibility…human-scale (photo: author)

Street Geometry: The Climate-Appropriate and Human-Scale Organic Grid

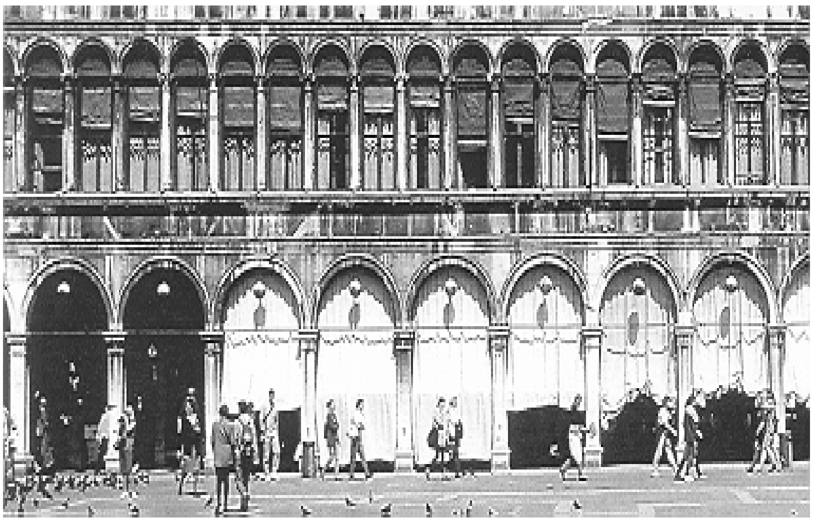
The climatic and human advantages of organic streetform cities have been attested to by urban theorists over the centuries. Vitruvius suggested directing streets away from prevailing winds; Alberti observed that winding narrow streets minimise the effects of climatic extremes; Cornelius commented that Nero enlarged the streets of Rome and it became hotter; and Palladio recommended that streets be broad in cities with cool climates, but narrow, with high houses for shade in cities with hot climates. Empirical evidence from tropical cities is found in the old-city of Dhaka, seeking shade not sun, with closely-packed, 3-storey high houses with distinctive narrow street frontages facing onto narrow streets.

> …it is better if the roads [in towns] are not straight, but meander gently - an ever-changing vista at every step, a view of the street for every house… (Alberti)

Largentiere, France: Car-rejecting old city/new neighbourhood (photo: author)

Shaded Pedestrian Streets or Roads for Cars?

> …medieval townsmen, seeking protection against winter winds, avoided creating wind-tunnels (broad, straight streets). In the south, the narrow street with broad overhangs protected pedestrians against both rain and the sun's direct glare. Frequently the street would be edged by an arcade…giving [even] better shelter (Mumford, 1961/91)



Venetian and North African shaded streets (Source: Behling & Behling, 1996, *Sol Power*)

By stepping back facades more sunlight reaches the city streets, an advantage in cold climates - a disadvantage in hot climates, where it is better to have buildings overhanging streets and shading each other, remembering always that sky-view is essential for night flushing of the heat accumulated in the urban mass. In contrast to such congruent models of urban form, modern and post-modern cities world-wide have taken on a generic 20th century form which defies ancient ingenious geometry, with buildings now independent of each other, coping separately with the climate - immensely influenced by Le Corbusier. Although he later recanted some of his more extreme views, in his *City of Tomorrow* (1924) the foundations for the modern climate-rejecting, culturally-indifferent, energy-profligate and car-polluting city were laid:-

> …a modern city lives by the straight line…the curve is ruinous…we should view the rectilinear cities of America with admiration...where the orthogonal [grid] is supreme, there we can read the height of civilisation…we must de-congest the centres of cities in order to provide for the demands of traffic…a city made for speed is made for success.

Urban Ventilation

Canyons

High-rise towers cause winds to be deflected downwards towards the side-walk, rain is driven laterally, dust is raised, and turbulent winds accelerate along the canyon created. However, Bosselmann et al (1995) show that streets lined with buildings up to four storeys high create shelter. Theoretically, where the streetscape is interspersed with shaded, air-cooled and water-cooled urban squares, parks and off-street courtyards (all acting as thermal vents), tunnel effects should be minimised as thermal-chimney effects are maximised. The organic urban streetform naturally breaks up the wind-tunnel canyon. Where set-back, overhang, height, and orientation vary and contour is respected, this can radically affect urban thermal currents and thus comfort experience and heat-health relationships.

Trees: Atmospheric Purification, and Natural Cooling

Natural air purification is performed by plants, trees in particular, which control temperature, air flow, moisture, and absorb odours and particulates, besides their fundamental role of sequestering carbon from CO_2 and oxygenating the air. Dust particles in parks are about 20 times less than elsewhere (Bernatzky, 1966); there is a 30% reduction in smoke concentration in Hyde Park, London, and about 60-70% SO_2 and NO_2 reductions in green areas (Robinette, 1972). More than half of ozone polluted air filters down to a forest floor (Waggoner, 1970).

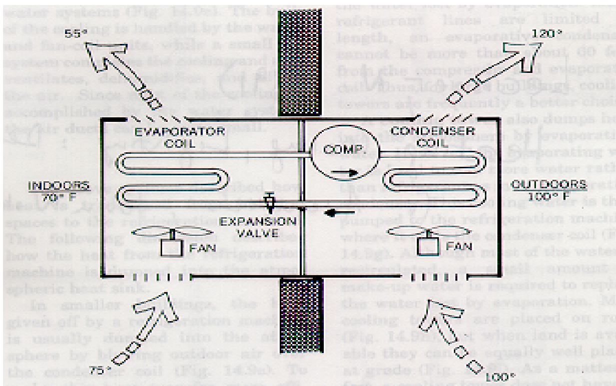
Simultaneously, trees are natural air-conditioners, transpiring and evaporatively cooling, while urban run-off from impervious surfaces robs cities of their natural evaporative cooling capacity. The temperature on a black tar road and on the grass in the shade of an adjacent tree varied by 14.5^{o}C (26.8 to 41.3^{o}C) when measured, at noon, in Sydney (author). This observation complements Givoni's (1991) of a 15^{o}C reduction in the temperature of walls shaded by trees. Multiplied tens of thousands of times, these impacts cannot be negligible. Integrating vegetation into buildings and onto rooftops is not a new idea: it is Babylonian in origin; while the dissemination and integration of green-life throughout cities is both aesthetic and pragmatic. Large parks separated from where people live and work are, possibly, an unfortunate throw back from walled cities where country was often separated from city. Overall, they might help cool a region, but it is the built-stock and urban infrastructure which requires active cooling; the micro-climate around each creating the urban macro-climate.

Earth-Cooled Buildings

Earth-bermed, earth-roofed, and subterranean urban buildings (Golany, 1989; Baggs, 1990) are practical solutions for hot cities - the earth, being both natural insulator and heat sink can assimilate thermal emissions before they are deposited in the urban atmosphere. Downtown Toronto (with moderately warm and humid summers, but freezing winters) enjoys an underground urban domain. Almost every downtown building can be reached by a network of tunnels, and 60% of Toronto urbanites use the underground public transport system to go to work (Bosselmann et al, 1995); again, mass transit heat emissions are neutralised by the earth. (Unfortunately, street life has been decimated, an important issue requiring resolution). Rotterdam, too, is currently developing underground domains linked to public transit systems. Fortuitously, subterranean buildings are also protected from untoward climatic disruptions – whereas light-weight, climate-appropriate buildings in hot, humid zones are increasing prone to destruction by more intense cyclonic activity.

Cool Buildings, Hot Cities

Inadvertently, refrigerative air-conditioning of buildings warms the urban domain. Heat is pumped from a building's interior (itself a heat sink) to the outdoor-air heat sink, raising its temperature by the amount cooled indoors.



Refrigerant air-conditioner, raising urban air temperature (by 20^{o}F here) (Lechner, 1991)

Although heat balance overall is largely neutral before and after transfer, the distribution is very different. Building interiors have thermal inertia (due to insulation, air gaps in walls and glazing, water storage, thermally massive materials…) thus removing heat from the urban climate (where it rises with rising greenhouse gases). Extending this logic, the refrigerant air-conditioning of cars, buses and trains adds insult to injury; not to mention the total energy expended for cooling, and associated greenhouse gas emissions. It might seem that urban warming might be advantageous if heat pumps (reverse-cycle air-conditioners) are used to bolster indoor temperature with heat extracted from the external air. But hot humid climates do not require heating. Notwithstanding, it is feasible to direct this waste-heat to sinks other than the urban air mass – the earth, or to water stored inside buildings (providing benign 'top-up' heating) - and remove it from the urban domain.

It is also the case that buildings are cooler under white or low-emissivity roofs than under black, require less cooling energy and eject less heat back into the urban atmosphere. But, ironically, white reflects more heat - which is deposited in the air sink, thus inadvertently warming the urban climate. If, on the other hand, heat extracted from the air (absorbed by black) could be channelled to an innocuous heat sink, could it not be removed from the urban realm? In any event, an uncomfortably hot street is likely to be shunned; and people will seek coolth indoors (often in shopping malls!) or stay inside buildings. Street life, again, is the victim.

Renewable Energy and Urban Ventilation

21st century cities will enjoy the advantages of cool power: solar power stations, energy-efficient buildings, materials and appliances, ‘smart’ building technology (heat, light and movement sensors) and smart energy management, photo-electric/photovoltaic (PV) cells and wind-turbines (Roger’s Turbine Tower, Tokyo) integrated into the building fabric itself - all cool energy sources. PV cells on rooftops, embodied in building facades and in the urban infrastructure, and photo-synthesis-simulating cells laminated into glazing are distinct possibilities once economies-of-scale make them affordable. Renewable power thus generated throughout a city could be stored on the electricity-grid, with the power station ultimately becoming *the battery; and* be used to power wind-turbines - which then generate power themselves. If strategically located in air-cooled parks and at the water’s-edge, such perpetual motion wind-machines could help ventilate hot arid and hot humid cities. Whether aesthetically acceptable is another question altogether.

21st Century *Climate-Change* Appropriate Cities

A high standard of living and the experience of a high quality of life are not necessarily equivalent. The very obvious expedient of being able to drive a car (our quintessential 20th century addiction) and breathing clean air or arriving on time (or, even, safely or gladly) are in most instances mutually exclusive. In a generic sense, the interactivity of global systems is so complex as to defy human understanding. Even the simplest interaction is mystifying: whoever could have predicted that hydrogen and oxygen would together make water? Neither governments, scientists nor industrial barons can solve the problem with their technological fixes. In many ways, believing that they can *is* the problem. Moreover, without a global ecological ethic and local energy literacy - without fundamental lifestyle-change - environmental design remains, ultimately, as *potential*: built-in but not operational. Under-developed nations race to catch up, over-developed nations jealously guard their standard of living. Give us renewable energy and we will use as much as we can, and inadvertently consume ourselves into extinction, while destabilising the global thermal balance; give us cleaner, more efficient cars and we will drive more and bigger vehicles more often, faster and further; allow nations and industrial-corporations the right to buy greenhouse gas and pollution emission vouchers and they will pollute more (and pass the cost on to the consumer).

The only reasonable logic at this point in time, in response to our unique 20th century urban planning experience, is the practice of precaution: consciously inseminate minds with a *sufficiency ethic*, pre-empt where possible, and prepare to adapt where necessary. For the first time in human history, millennium-paradigm climate-appropriate design is about to be superceded by climate-change imperatives. Future research should develop an Urban Thermal Pollution Index: determining and evaluating heat-emission indicators (sources and sinks) – to complement post-Rio energy-$CO_{2\text{-}e}$ emission inventories.

Given that population numbers, energy and resource consumption, and greenhouse gas and heat emissions continue to increase exponentially, will renewable energy cities, carbon-heat sink cities, naturally-cooled cities, climate-change appropriate cities (*old cities for new climates?*) emerge rapidly enough to avoid melt-down? One essential belief at the core of the ecological ethic is that we are a part of nature, not apart from it; whatever we do to nature we do to ourselves. Indeed, the new discipline of eco-psychology focuses on this separation anxiety, a 20th century malady. Built environment practitioners continue to perceive buildings as separate from each other and from their urban context; and urban climate is overlooked with monotonous regularity. Little matter that the "millennium" is a Christian, western myth (only starting officially in 2001 anyway), the magic of the number 2000 and the potency of this once-in-a-thousand-year opportunity seems able to mobilise planetary consciousness. It is a special responsibility to ensure that it does.

> In the end the crucial change is attitudinal
> (David Suzuki, *The Sacred Balance*, 1997)

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