URBAN CLIMATE DESIGN IN THE EQUATORIAL MEGAPOLIS: KEY CHALLENGES TO EFFECTIVE ADAPTIVE ACTION

CLIMA URBANO E PLANEJAMENTO EM MEGALÓPOLES EQUATORIAIS: PRINCIPAIS DESAFIOS PARA UMA EFETIVA AÇÃO ADAPTATIVA

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ABSTRACT
Climate-sensitive design is gaining prominence due to its links to good design as well as the increasing awareness of the need to mitigate and/or adapt to the changing climate. This is especially the case in the urban tropics, the changing urban microclimate further confounds the already difficult design problem of designing with climate. This paper summarises the key climate-sensitive design challenges in the rapidly growing tropical megacities – a region of immense importance not only due to the rapid population increases but also due to its growing economic clout. Given the knowledge base on the climate–urban growth nexus in the tropics, the paper lists three key challenges offere in outline form, likely paths research planning/design may take in the coming decades.

KEYWORDS: Climate-sensitive design. Tropical megalopolis.

RESUMO
O planejamento e o desenho urbanos climaticamente responsáveis estão ganhando proeminência devido às ligações desses com o projeto de qualidade, bem como à crescente consciência da necessidade de mitigar os efeitos e/ou adaptar as cidades à mudança climática. Esse é especialmente o caso da urbanização nos trópicos, onde a mudança no microclima urbano confunde ainda mais a já difícil tarefa de projetar com o clima. Este artigo sumariza os desafios da questão do projeto urbano climaticamente responsável no contexto das megacidades tropicais de rápido crescimento – uma região de imensa importância, não apenas devido ao rápido aumento populacional, mas também por sua crescente influência econômica. Dada a base de conhecimento sobre a interação do clima com o crescimento urbano nos trópicos, o artigo lista três desafios-chave e oferece, numa forma esquemática, os caminhos prováveis da pesquisa e do planejamento/projeto nas próximas décadas.

PALAVRAS CHAVE: Projeto climaticamente responsável. Megalópoles tropicais.

1 INTRODUÇÃO

There is increasing consensus that well designed built environment is synonymous with sustainable design. For example, the U.K Commission on Architecture and Built Environment (CABE) considers that "sustainable design is an integral part of good design. No building, space or place can be considered well designed if it does not contribute to environmental, social and economic sustainability. Conversely, no building, space or place can be considered sustainable if it is not well designed" (CABE, 2008). Among the various definitions for sustainable design, one that is relevant to an architectural discussion is design that is true to its environmental, social, economic and programmatic contexts. Climate is intrinsic to all four and therefore plays a vital role in the creation of sustainable built environment (EMMANUEL, 2010).
Climate is inseparable from the environmental context of the built environment. It determines the nature and severity of the environmental forces that impinge on the building envelope and influences the soil as well as the flora and fauna of the surroundings. Climate also influences the social milieu in which design occurs: the all inclusive concept of “culture” is heavily influenced by climate and is woven around the seasons, extremes and variations in weather parameters. In most cases, the building’s brief (i.e. programme) does (or at least ought to) reflect the climatic context in which the building is created. Economy of design can only occur if the built environment works WITH climate and not AGAINST it (EMMANUEL, 2010).

However, there are several challenges in applying climate knowledge to the creation of built environment in a manner conducive to sustainable living, especially in the developing world. The design standards and expectations are rapidly evolving in the context of unprecedented urban population growth. Climate itself is changing, more so in the rapidly growing tropical megacities (global as well as meso- and micro-climate changes). Climate data are not readily available, or when available, not readily usable by building designers. The spatial and temporal scales at which climate data are needed by the creators of urban and built environment are not easy (or cheap) to produce. To confound matters further, the interaction between climate and the built environment is governed by the uncertainties of global and regional climate change augmented by the inadvertent climate consequences of urban built environment (the “urban heat island” effect, LANDSBERG, 1981).

This paper summarises the key climate-sensitive design challenges in the rapidly growing tropical megacities – a region of immense importance not only due to the rapid population increases but also due to its growing economic clout. Having listed what is known of the climate–urban growth nexus in the tropics, we turn our attention to the key challenges and offer in outline form, likely paths research and planning/design may take in the coming decades.

2 BACKGROUND

The nexus between urban design and climate is predicated on the fact that cities generate their own local to meso-scale climates. The phenomenon of city-induced environmental change has been known for many centuries, from ancient Indian architectural manual Silpaśāstra to Roman treatise on architecture (Vitruvius’ [75 - 25 BC] Book I of the Ten Books on Architecture, cf. EMMANUEL, 2005). However, the experiential awareness of city-induced climate changes and intuitive knowledge of mitigation strategies were not systematically studied until the development of meteorological instruments such as the thermometer, the barometer and the anemometer (cf. OKE, 1991: 61). The widespread availability of meteorological instruments in the mid-nineteenth century heralded what could now be termed as the “scientific” investigation of urban microclimate modifications. Luke Howard (1818) is credited to have carried out the first scientific study of inadvertent urban climate modifications (LANDSBERG, 1981). He compared the temperature records of a city weather station with that of a few (then) rural stations (see MILLS, 2008 for details) and found that the city station was warmer. The warmth of cities in contrast to their rural surroundings is now called the “urban heat island” (UHI), a term – according to Landsberg (1981) – probably coined by Gordon Manley in 1958, although reference to a “heat island effect” was first noted in Balachin and Pye (1947).

A heat-island is best visualized as a dome of warm air, over the heavily built-up areas of cities. UHIs have been observed practically in all parts of the world. Contrary to the conventional wisdom, heat-islands are intense at night, occurring a few hours after the sunset. This has far-reaching implications for urban design in the tropics where night-time thermal stress is comparatively low. A detailed review of literature, possible causes and state-of-the-art in terms of research and applications is available in a separate WMO Technical Note (TD 149 [CHANDLER, 1976] and amendments) and Oke (1987).
3 ENERGETIC BASIS OF TROPICAL URBAN HEAT ISLANDS

Oke (1987) provides a comprehensive treatment of the urban energy flows. Urban areas significantly alter both the sources and the sinks of the heat flow mechanisms. Two heat sources, net all wave radiation and anthropogenic heat and three heat sinks, sensible heat loss, latent heat loss and storage are important in urban thermodynamics both at the layer where much of life occurs (the so-called Urban Canopy Layer – UCL) and above the UCL where the urban effect is discernible (the Urban Boundary Layer – UBL). Industrial and manufacturing activity, automobile heat rejection and building energy wastage appear to be significant heat sources for urban areas. However, there are wide temporal and spatial variations in the intensities of such anthropogenic heat sources. While there is more building energy waste in the heating seasons than the cooling seasons in temperate climates, this has now reversed in the tropics. Spatially, downtown areas contribute more per unit area than the suburbs and residential zones of cities. Overall however, the role of a spatially and temporally averaged anthropogenic heat input seems relatively minor. Although data does not exist for tropical cities, it is not likely to be different as the industrial vitality and climatic need for greater energy wastage do not exist in that region.

On the sink side of the equation, heat storage in the urban fabric appears to be the primary flow mechanism at the urban canyon level. At the boundary layer level however, heat storage plays only a modest part in trapping urban excess heat.

It is in the relative partitioning between sensible and latent means of heat flow that urban areas appear to exert the most influence. At the UCL, urban morphology (especially the street geometry formed by building heights and street width) and surface thermal properties dictate the relative proportions of sensible and latent heat loss. At the neighborhood scale and larger, moisture availability and by inference, the presence/absence of vegetation appears to be the critical control.

4 CRITICAL ISSUES

Although the study of the tropical urban climate anomaly is relatively recent, it has advanced enough for tropical urban planners and designers to utilize the knowledge base to improve the quality of life of the ever increasing urban populations. While the scientific basis is not perfectly understood, the urgency of need requires action, even if only supported by partial knowledge.

Three possible issues are posited as key to the utilization of knowledge already gained. They also point to key research and design challenges for the immediate future.

a. Design strategies – especially to promote shading while facilitating ventilation

Morphology

The amelioration of the urban climate anomaly in the tropics increasingly point to the need for shade. For too long the emphasis has been on ventilation, to the detriment of all other climate-sensitive design options. While there is no denying of the cooling effect of urban breeze, wind’s cooling potential is greatly enhanced if accompanied by shade. Coupled with the difficulties arising out of increasing built density, need for privacy and poor air quality, ventilation strategies by themselves will struggle to achieve the desired comfort. It is necessary to link them to other design approaches, especially shading. A serendipitous by-product of design focus on shade is the possibility of accommodating very high density urban living, provided the densities are achieved without compromising the climatic quality of public places (EMMANUEL, 2009).

Our efforts towards such a realization have been underpinned by a concept introduced in the 1990s as “shadow umbrella” (EMMANUEL, 1993). The approach is the reverse of the “solar right” movement in temperate climates, which seeks to ensure adequate sunlight to all buildings. What we advocate is an urban design ethos of shading of public places (i.e. a subversion of the solar right principle of “thou
shall not cast shadow on thy neighbor’s property” to a tropical axiom of “thou SHALL cast shadow on public spaces!”

Greenery

The apparently high building density in the tropics is not so much due to high rise buildings, but because the occupancy rate per room is high (CORREA, 1989: 42). Every available space is illegally built upon by urban migrants. There is a critical need for open space in tropical cities. Unplanned sub-divisioning of city land partitions even the little open space available into private, but thermally and ecologically insignificant backyards. While open space in a temperate city like London is 3 ha per 1000 people, Delhi has only 1.5 ha per 1000 people. A tropical city like Bombay has only 0.1 ha. This paltry amount includes even the grass on traffic islands (CORREA, 1989: 42).

While the case for urban greenery in the tropics is clear, there are still unresolved issues in terms of enhancing whole-day thermal comfort. One of the critical issues is to enhance our understanding of how to benefit from tree shade without nighttime warming. This is especially problematic in residential areas where day- and night-time cooling are critical for thermal comfort. Other urban vegetation issues include water availability, maintenance, air quality and effects on local bio-diversity.

b. Nexus between climate-sensitive design and urban transportation

All urban activities start and end on foot. And in high density cities what goes in between is more likely to be on foot than on any other mode. Even a motorized city like New York depends for a large part, on pedestrianization. It is estimated more than 70% of all rush-hour traffic in Manhattan is on foot (WRIGHT, 1992). The situation in tropical megacities is even starker. For example, two- and four-wheeled transport has “overwhelmed the streets in almost every large Asian city, creating unbridled congestion and long commute times... Building more roads and flyovers cannot hope to catch up with the trends. This challenge can only be met with a new approach to sustainable transport” (WRI, 2007: 13). Enlightened city authorities in Europe, including Amsterdam, Stockholm, Athens (HAVLICK, 1983) and Copenhagen (GEHL, 1989) have re-organized city street networks so as to facilitate a climatically and aesthetically appropriate growth. The tautology of mass transit and density (“Mass transit will not work unless density is high: People will not live densely until a good mass transit system is established”) can be solved only by moving in the direction of high-density development and pedestrianization simultaneously (EMMANUEL, 2005).

Once two pre-conditions are met, a new approach to climate-conscious design in the urban tropics can be attempted: design of accessible public spaces and pedestrianization. In the tropics, this calls for the integration of urban transportation planning and climate-sensitive urban design. However, the following critical issues must be addressed before we embark on such an integrated approach:
- Air quality: dispersal of urban pollutants is hindered by high density building arrangements. Studies on pollution dispersal and high density living are still at preliminary stage.
- Noise/privacy: high density living needed to make sustainable urban transport work needs to take cognizance of noise pollution and the increasing need for privacy. Open design that promotes ventilation has conflicts with this requirement.
- People vs. goods movement: even if sustainable urban transport strategies are adopted for people movement, some degree of non-people transport will have to rely on mechanized modes.

c. Data needs in the urban tropics

Emmanuel (2010) summarized climate data needs of the built environment sector into three broad categories:
- i. Data in support of good design practice;
- ii. Data needed for building performance monitoring and evaluation;
- iii. Data needed for emergency management / disaster preparedness in the built environment sector.
These needs are highly accentuated in the resource- and science-poor tropical regions; yet the needs are all the more great on account of the rapidly rising urban populations. For the purpose of simplicity, it may be suggested that good design practice is based on long-term average historic data while performance monitoring and evaluation requires current and/or recent historic data. Current climate data and weather forecasts at different time intervals are needed for emergency management purposes although disaster preparedness may rely upon long term historic data.

A critical need for the built environment professional is reliable and detailed local (and meso-scale) climate data especially in urban areas. Oke (2006) provides an excellent guide to such efforts. It is also necessary to provide detailed climatic information as databases in Geographic Information System (GIS) platforms and in the form of digital elevation models (DEMs). Reliable and detailed stand-alone data files usable as input files for building simulation are also needed.

One of the critical needs in the urban tropics is reliable design values appropriate for urban built environment in the tropics. Prescriptive codes and standards for building performance often rely on a suite of “typical meteorological conditions” derived from long term climate data. These climate summaries, variously known as the Design Summer Year (DSY) or Design Reference Year (DRY) in the U.K. and Typical Meteorological Year (TMY) in the U.S. codes offer critical templates. Some recent examples of such codifications – Chow and Fong (1997) for Hong Kong; Kalogirou (2003) for Cyprus, Skeiker (2004) for Damascus, etc. – might offer interesting examples. A simple process for the calculation of TMY from sunshine duration (as opposed to global radiation) is given in Ecevit et al. (2002). The latter is particularly useful in the tropics where the availability of global radiation data is patchy or non-existent.

5 FUTURE DIRECTIONS

a. Design aids, tools and exemplars specifically for the urban tropics

The planning and design processes are not entirely “rational”. Opportunities for intervention are not always readily discernible. On the one hand, competing sets of priorities vie for the attention of planners and designers while on the other hand, an information overload leads to paralysis of inaction. It is necessary to communicate the climatic information and the climatic consequences of design choices in a form readily discernible and more importantly, readily usable by the design community. Design aids, exemplars, checklists, manuals and tools can address this need.

The integration of urban climate knowledge with the design process will greatly benefit from integrating the current generation of research tools on building and urban thermal/climate simulation with CAD platforms commonly used by designers. The aforementioned research tools remain largely unused by architects and planners in their day-to-day design decision making processes. While this is to be expected due to the technical complexities of the tools themselves, what is missing is that climatic consequences of design decisions are not being provided to the designers at critical junctures in the design process. At the same time, many designers/planners do use computer-aided drafting/designing tools extensively and there is an opportunity to integrate some aspects of the climatic simulation tools with the computer-aided design tools (for example, thermal properties of building materials, shading/ventilation consequences of built massing, etc., could be added as additional “layers” within CAD platforms). Previous successful efforts in integrating building design/drafting tools with resource management, site space utilization and planning of building construction (so called 4D CAD tools, CHAU et al., 2005) might provide a useful conceptual model to integrate climatic information with design/drafting tools. An early effort in this area was recently reported by Asawa et al. (2008).
b. Detailed local climate data

A major difficulty in collecting detailed local climate data is the reluctance of meteorological authorities to site observation stations in built up urban areas (EMMANUEL, 2010). It is true that the nature of urban built up spaces makes it difficult to conform to the standard guidelines for site selection and instrument. However, a balance is needed between “representative” data and “useful” data.

If the objective of an instrumented urban site is to monitor the local scale climate near the surface, there are two viable approaches (OKE, 2006):

(a) Locate the site in the Urban Canopy Layer (UCL) at a location surrounded by average or ‘typical’ conditions for the urban terrain, and place the sensors at heights similar to those used at non-urban sites. This assumes that the mixing induced by flow around obstacles is sufficient to blend properties to form a UCL average at the micro scale;

(b) Mount the sensors on a tall tower above the Roughness Sub-Layer (RSL) and obtain blended values (local scale) that can be extrapolated down into the UCL. In general, approach (a) works best for air temperature and humidity, and approach (b) for wind speed and direction and precipitation. For incoming radiation, the only significant requirement is for an unobstructed horizon” (WMO, 2008: II 11-5).

c. Knowledge transfer to/from the tropics

There is a yawning gap between those places where urban climate research is done and those places where this information is most needed. The bulk of urban climate research is conducted in the more developed regions characterized by mid-latitude, temperate climates. By contrast, the bulk of the urban population of the planet lives in tropical cities of the less developed regions.

At the same time, experiential awareness of living in a warm world and research and design for a rapidly warming urban world is available within the tropical urban climate research community. As the world becomes generally warmer, there is a need to learn from a two-way knowledge transfer to/from the tropical world. Mills et al. (2009) suggest the following strategies to overcome critical barriers to effective knowledge transfer:

Absence of research: more research on urban climates in the warm, humid and hot, arid regions is needed. In the absence of local research capacity, greater collaboration between well-resourced urban climate experts and those with locally-based knowledge is required. Among the issues needing attention are means for promoting urban-scale ventilation, providing urban shading while allowing pollution dispersal and dealing with urban thermal discomfort in year-round warm climates.

Institutional issues: there is an under-representation of issues of significance to developing world cities in international networks and fora. This is partly due to lack of research capacity in developing regions focused on cities. A program of planned expansion of training of urban climatologists and designers/planners from the developing world is needed to widen the global knowledge transfer efforts. Such efforts must be cognizant of the issue priorities relevant to developing cities.

Absence of reliable data: in general, useful meteorological data is in short supply so that there is a lower expectation of obtaining reliable and spatially/temporally appropriate information. In order to overcome these difficulties we need improved attitudes to data, intellectual property rights, etc.

Communication: much of the published work on urban climates appears in English language journals that are not available in many developing regions. Where research work is completed in tropical cities it is often published in non-English regional journals. As a result the fruits of urban climate research are not known in those places that need it most. Similarly, a rich source of local urban information is not incorporated into mainstream urban climate knowledge. These are further confounded by weak knowledge dissemination networks in the tropics/sub-tropics.

Even the little that is known needs to be widely disseminated for effective use by the planning and
design professions. Structural and institutional changes are needed to address these issues and such changes are needed to foster appropriate research and two-way knowledge transfer.

6 CONCLUSIONS

The challenges facing tropical cities are two-fold – unique urban growth and unprecedented rate of growth. Tropical urbanization is unique in that it is not accompanied by industrial growth but is driven by a large-scale migration of humanity in search of opportunities. It is unprecedented in the sense that such a growth is occurring within the space of a single generation. Tropical cities, especially the mega-cities, need unique and rapid solutions. The population densities which need to be accommodated at such rapid speed are truly mind-boggling. The challenge is further complicated by global warming which is making an already “problematic climate”, as Trewartha (1981) put it, nearly intolerable. While this might appear a daunting task, our understanding of the urban heat island effect in the tropics, its causes and especially its mitigation, offers hope that the same human-induced urban changes can be harnessed to enhance the climatic quality of our cities. An enlightened approach to urban design is therefore needed in the tropics. Rather than merely replicating the failing models of urbanity from the West, tropical cities need to chart a shade-oriented, ventilated design ethos for their public spaces.

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