The effects of improved built form on urban cooling: review of passive strategies and urban design case studies

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Abstract:
With the current rapid pace of construction in South East and East Asia, built form and blocks are changing significantly, having impact on the building physics and environmental performance of macro [urban] environments. Such change at macro scale has major impact on how spaces and blocks are shaped and developed. This has direct impacts on urban ventilation systems (both passive and active) and the built form or physics of the urban environments, including but not limited to, orientation, layout, massing and form. The paper reviews the various opportunities for macro cooling via improved built form for urban residential environments and will further explore possibilities of urban cooling for the context of Asia. This paper specifically includes tropical and the warming sub-tropical areas of Asia.

Keywords: *Urban; Cooling; Built Form; Environment; Macro; Passive*

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1. Introduction

Urban environment is a major factor for individual health and comfort, and for both micro and meso scale climate change including the urban heat island effect (UHIE). In a rapidly urbanising world, particularly in the developing context, urban climate is a major issue. Challenges include urban cooling, green-blue infrastructure and many aspects of built form and spatial planning. Improvements in these can reduce energy needs and make living environments more efficient and comfortable. This study discusses cooling at macro scale, with particular focus on passive cooling of residential urban environments. We discuss urban layout and typology, limitations of water and vegetation, and the integration of these in macro design of urban environments. We explore methods of improvement for built form at macro level giving positive impacts on the heat island effect and cooling. Many studies have addressed these issues and this paper will add focus on implementation of available methods in practice.

2. Background

Urban populations are increasing very rapidly, especially in developing countries. Not least because this is often the more affluent population segment, their energy use and climate footprint will increase very rapidly in the case of conventional development and urban planning. This is a major energy and climate challenge facing the tiger economies and others. In hot climates, cities may be two to five degrees warmer than the surrounding region (Rosenfeld et al., 1995), and ther major energy need is for cooling. Modern cities need to provide a healthy, comfortable environment, and to drastically reduce their ecological footprint, which today corresponds to fifty or several hundred times their own area (Best Foot Forward Ltd., 2002). Today's solutions are not the answer.

This urbanisation and its future climate and energy load is already causing alarm. As one example, '*almost 80% of the residential construction projects in Xiamen Island were built after 1990, whereas only 6.7% of the construction was built before 1980*' (Ye et al, 2011). According to the International Energy Agency, by 2035 China might be using one fifth of all global energy, a 75% upsurge since 2008 (IEA, 2010). The trend is similar in many developing countries with rapid urbanisation. Sustainability demands attention to macro scale even more than the micro scale of individual buildings.

3. Brief Case Studies

Case 1 – Urban Cool Islands (UCIs) and Green Spatial pattern of Nanjing

The urban cooling effect is a key to identifying spatial pattern of greenspaces in a city. This was studied by Kong et al. (2014) who looked into green spaces, not as the UCIs of the city but mainly as ‘Greenspace Cool Islands (GCIs)’. They studied Nanjing, a large metropolitan area of Eastern China. Nanjing’s summers, exceeding 40 degrees on three occasions since 1951 (Miao et al., 2008), show a significant raise in mean temperature. Based on their studies, the land-use map of the areas provides knowledge regarding surfaces, available vegetation, and more importantly, spatial patterns of greenspaces for urban cooling. The characteristics of GCIs intensity are identified and expressed as a way to incorporating such features into urban design and planning (Fig. 1).

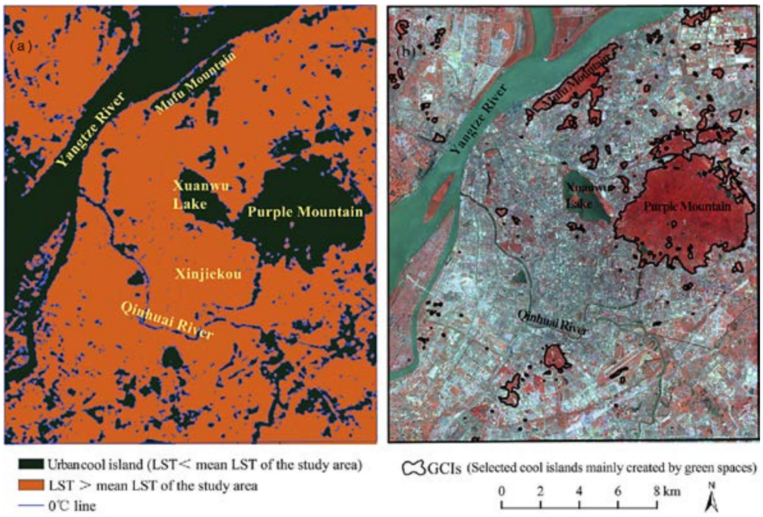

Fig. 1 (a) Image used to identify urban cool islands (UCIs) where the land-surface temperature (LST) is less t han the LST for the study area, City of Nanjing. (b) The greenspace cool islands (GCIs) in the study area, Na njing (Source: Kong et al, 2014).

It is difficult to predict or model the impact of GCIs on urban cooling. However the relationship between greenspace spatial patterns and urban cooling can be analysed to evaluate the effects from landscape planning and greenspace land-use. In the same study, analysis is undertaken through numerical modelling in order to scientifically understand cooling effects of GCIs (and their intensity) for urban environments. Mitigating the impacts of UHIs is a major issue for city planning. For this selected study, the approach is all passive and requires careful consideration of planning and design (including urban landscape design) at a city scale. The modelling of GCIs helps to develop a comprehensive framework for green (and blue) infrastructure of the city.

Case 2 – Eco-city Masterplan in Tainan County

Bioclimatic Urban Design and Integration of City and Countryside

GAIA International was commissioned to develop a new Eco-city in Tainan county, southern Taiwan (Butters, 2014). Their master plan adds a new dimension to the concept of sustainable cities by developing a vision for integration of city and countryside (Fig. 2). Most eco-city concepts address the urban dimension in isolation. By contrast, GAIA’s strategy shows that the hinterland is a necessary part of a coherent systemic vision of sustainable human settlements, and that city-country integration offers synergy effects and economic opportunities. The concept develops connections between rural and urban subsystems. These include mixed-use spaces, sustainable water and waste cycles, food production and renewable energy cycles. This vision also addresses the rural poor – a cause of migration to growing city slums.

Fig. 2 Ecocity Tainan, Masterplan by GAIA International with Joachim Eble, Varis Bokalders and C hris Butters, in collaboration with EDS Design Services, Archilife Foundation and Tainan County g overnment, 2005-07.

GAIA redefined the boundaries for the city, to include the surrounding countryside. In this way many resource flows can be optimised and integrated. The layout of streets and typology of building masses is based on bioclimatic principles. Priority is on energy efficiency, reduced traffic, water recycling and green corridors. These passive design strategies reduce resource needs before selecting the supply side solutions. Features such as green corridors reaching into the city fulfil specific microclimatic functions. Similarly, street orientation and geometry is not simply aesthetic design but optimises solar orientation, shade, wind and urban ventilation – providing an improved cooler microclimate. Climate and ecology thus become key generators of urban form. The city is zoned into four areas of different character and density, to integrate workplaces and illustrating that sustainable typologies can range from dense city blocks to low-density garden suburbs, plus rural villages. A major obstacle to urban sustainability is the private car. This is not just about fuel use but about liveable, child friendly streets and healthy, noise-free outdoor spaces. Much of the land around this eco-city is used for a struggling sugar cane industry. This is ideal for developing biofuels since it would not compete with food production. It could quite literally become the petrol station for the city – local and renewable biofuels.

4. Discussion

Our case study based review highlights aspects that are important for urban cooling and design. These include:

a) Paradigms

Integration of town and countryside as in the Taiwan proposal is one vision. Eco-communities, such as Hjortshoj in Denmark (Butters c. et al, 2012), have a modern lifestyle but their footprints are as l ittle as one third of the national average (GEN, 2006). Various models around the globe offer possib ilities for new settlement paradigms. Yet such paradigms need to be contextualized and localized in regard to climatic, ecological and cultural aspects. There cannot be a global model but several possi ble new settlement paradigms.

b) Zero Emission Solutions

The Kronsberg development in Hannover, Germany, was an early pioneer for zero carbon cities (Ha nnover.de). Already from 1992 this large new urban area was developed with a range of strategies i ncluding passive design, energy efficiency, renewable energy, user information and participation. T here was also strong focus on water, wastes, jobs, urban and social qualities. By 2004 one could sho w carbon emissions of only around one quarter of conventional cities. They noted that the last quart er would need to be covered by renewable supplies from outside the city limits – if not by major be havioural reductions in car use or energy.

c) Compactness

Density is a key theme in the urban debate. The compact city presents some advantages in terms of sustainability, notably for transportation. But when urban quality is evaluated in a holistic way, such as with the Sustainability Value Map (Butters, 2012), there are many arguments for openness, inclu ding noise, pollution and not least, plentiful green spaces, which assist urban cooling. The term 'co mpact' can be understood in two ways: a) as urban form where the buildings and structures become even denser and more compact than before; and b) as '*an increase in density, so that more people a nd, one might expect, more urban functions are located within a given area*' (Scoffham and Vale, 19 96). Both aspects seem equally important mainly because compactness will necessitate an increased density in occupation and activities that an urban area can offer.

d) Low-Income, upgrading and remodeling

Whilst cities are vital, we must not overlook rural contexts or the millions living in slum conditions. Their energy and climate impact is small, as of now, but their living and health conditions are poor and deserve equal attention. Conditions might be dramatically improved, also avoiding increases in energy use, through simple refurbishment interventions at a low cost.

e) Barriers and drivers

The climate agenda and its targets are drivers of change today. But a precondition is sufficient planning and governance structures. There are also many barriers of a sociological or cultural nature, such as perceptions that concrete is more desirable than adobe, or that air conditioning is an essential status symbol. Barriers to change are often far from purely economic or rational. There are structural issues too, such as property markets and legal systems. Why are good principles seldom followed - and are regulations, incentives, pilot projects or education the answer? Many methods may not be available or effective in a given context. As one study of possible strategies for energy efficiency in the Chinese city of Ningbo concludes – 'the discussion of suitable countermeasures shows that only enhanced supervision strategies are currently applicable' (Yao et al., 2011).

5. Conclusion

Today, most urban cooling is by individual air conditioning (AC) units. In addition to requiring high quality electric energy these increase the heat island effect – each unit sending more heat to its neighbours. AC is also costly and therefore inaccessible to the poorest. Although more efficient AC technology is part of the solution, this does not address the first rule of energy planning which is first to reduce the demand. Experience worldwide is showing that efficiency gains are almost invariably eaten up by increased consumption, meaning that our total energy use and emissions continue to rise. Our research includes extensive literature reviews on topics of urban cooling and urban physics and analysis of selected cases, ranging from high density to average urban residential typologies. This applies not only to the spaces and buildings, but also to transport planning and zoning for integrated mixed use. At the other, user end is the question of human comfort needs and responses in urban surroundings, particularly in hot climates. Sustainable planning principles are much debated, and further inquiry concerns the barriers which hinder wider application in the real world.

To what extent can good, energy conscious urban planning and design provide lower energy needs and climate impacts and comfortable urban environments - both indoors and outdoors - with a minimum of active technological aids? The well-known keyword is 'design with climate' (Olgyay 1963, McHarg 1969, Szokolay 1991, Givoni 1998) whereby the natural factors, as opposed to aesthetics or nature-defying solutions, become key generators of urban form.

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