ARCHITECTURAL AND URBAN DESIGN INTERVENTIONS TO MITIGATE IMPACTS OF URBAN HEAT ISLANDS ON URBAN DWELLERS

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ABSTRACT

Urban Heat Islands (UHIs) have become a known fact, causes of which include increased urbanisation, increased urban activities, e.g. increasing number of vehicles on the road, and more polluting industries etc. High rise buildings obstruct cooling winds and also absorb and radiate heat. Urban areas use the natural resources like water, land, air etc. and return these back to nature in the form of waste and pollutants. Temperature is determining element for human comfort. Some of the physiological effects of thermal heat stress include increased blood flow to skin, sweat and increased ventilation. In tropical countries where heat is a predominant feature, exacerbation of UHIs is witnessed effecting the health of the Urban dwellers. This paper attempts to analyse the UHIs through literature review, discuss its effects and recommend solutions at all the scales of design interventions vis-a-vis., Building level, Urban scale, Neighbourhood scale, Community level, Meso level and Town/ City level. For e.g. White paints on the roofs decrease the roof surface temperature by 20%.

Key words: Architecture, Heat Illnesses, Heat waves, Urban Design, Urban Heat Islands.


1. INTRODUCTION

The human’s desire for comfort and economic means of survival with lesser time and investment, more rural to urban migrations, Urban areas are becoming more denser and more congested resulting in increased population, increased vehicular traffic, increased power consumption for cooling, increase in pollutions of all types vis-a-vis air, water, sound, visual, radiative, thermal pollution resulting in Urban Heat Islands (UHIs) especially in tropical countries where heat is the predominant climatological feature. These effects of urbanization are resulting in physical and mental stresses on city dwellers as individuals.

This exploratory research paper aims at identifying the ill effects on the human beings and exploring recommendations to mitigate the UHIs at all scales of design interventions. Due to various characteristics and aspects of urbanization, mental and physical health of the urban dwellers are adversely affected. The purpose of this paper is to emphasise the ill health effects of UHIs. This paper provides recommendations to reduce the UHI effects and shows how to cope up UHI’s effects with the help of Architectural and Urban Design Interventions, Strategies and policies have also been discussed.
2. LITERATURE REVIEW

Urban areas use the natural resources like water, land, air etc. and return these back to nature in the form of waste and pollutants. Due to this, the urban environment is deteriorating day by day rendering the quality of life in urban are as deleterious, resulting in negative health effects. Urbanisation in the first place changes the land use pattern, alters the natural drainage pattern, transforms the green fields to urban hard paved surfaces etc.

Temperature is determining element for human comfort. An Operative Temperature of $22^\circ$C in winter and $25^\circ$C in summer is comfortable range [1]. Performance of a person under thermal stresses is about 11% lower than their performance at normal thermal conditions [2]

Some of the physiological effects of thermal heat stress include increased blood flow to skin, sweat and increased ventilation.[2]

![Figure 1 Performance capacity of Humans under thermal Stresses][2]

In 2015, heat waves caused a death toll of 1800 and each year heat related death toll and illnesses/sicknesses are increasing [4] 61% rise in heat-stroke deaths over decade across India is seen [5].

3. URBAN HEAT ISLANDS (UHIS)

Many urban and suburban areas experience elevated temperatures compared to their out-lying rural surroundings; this difference in temperature is what constitutes An Urban Heat Island.[6] The phenomenon was first investigated and described by Luke Howard in the 1810s, although he was not the one to name the phenomenon[3]. The annual mean air temperature of a city with one million or more people can be 1°C to 3°C warmer than its surroundings, and on a clear, calm night, this temperature difference can be as much as 12°C [7]. Even smaller cities and towns will produce heat islands, though the effect often decreases as city size decreases [8].
Urban heat islands refer to the elevated temperatures in developed areas compared to rural surroundings. Urban heat islands are caused by the changes in radiative and thermal properties of urban infrastructure as well as the impacts buildings can have on the local micro-climate—for example tall buildings can slow the rate at which cities cool off at night. The impacts from urban heat islands and global climate change (or global warming) are often similar. For example, some communities may experience longer growing seasons due to either or both phenomena [8].

3.1. Types of UHIs

3.1.1. Surface Urban Heat Islands
On a hot, sunny summer day, the sun can heat dry, exposed urban surfaces, like roofs and pavement, to temperatures 27°C to 50°C hotter than the air, while shaded or moist surfaces—often in rural surroundings—remain close to air temperatures. Surface urban heat islands are typically present day and night, but tend to be strongest during the day when the sun is shining.[8]

3.1.2. Atmospheric Urban Heat Islands
Warmer air in urban areas compared to cooler air in nearby rural surroundings defines atmospheric urban heat islands. Experts often divide these heat islands into two different types

Figure 2 This conceptual map with overlaid isotherms (lines of equal air temperature) exhibits a fully developed night time atmospheric urban heat island. The dotted red line indicates a traverse along which measurements are taken. [8]
Canopy layer urban heat islands exist in the layer of air where people live, from the ground to below the tops of trees and roofs.

Boundary layer urban heat islands start from the rooftop and treetop level and extend up to the point where urban landscapes no longer influence the atmosphere. This region typically extends no more than one mile (1.5 km) from the surface [8]

4. FACTORS THAT CREATE URBAN HEAT ISLANDS

Urban areas generally have higher temperatures than the nearby suburbs and rural areas. One reason for this is the heat generated due to the various urban activities, e.g. greater number of vehicles on the road, and more industries (often polluting ones). High rise buildings obstruct cooling winds and also absorb and radiate heat [9]. For example, paved roads also act as heat absorbers. A combination of these results in the creation of urban heat islands. At times, the urban heat islands of two nearby urban areas merge, affecting the climate of the region. As urban areas develop, changes occur in the landscape. Buildings, roads, and other infrastructure replace open land and vegetation. Due to urbanisation, many surfaces become impermeable. This development leads to the formation of urban heat islands the phenomenon whereby urban regions experience warmer temperatures than their rural surroundings. The lesser-used term heat island refers to any area, populated or not, which is consistently hotter than the surrounding area. Reduced vegetation in urban regions reduces the natural cooling effect from shade and evapotranspiration. Properties of urban materials contribute to absorption of solar energy, causing surfaces, and the air above them, to be warmer in urban areas than those in rural surroundings [8].

4.1. Factors to Consider

The amount of radiation received and emitted back also depends on the Surface Area of the Urban structures. Anthropogenic heat emissions contribute additional air temperature.

4.2. Additional factors

Weather conditions, such as clear skies and calm winds, can foster urban heat island formation. Geographic proximity to large water bodies and mountainous terrain can influence local wind patterns and urban heat island formation [8].

5. RECOMMENDATIONS

All the surfaces of each structure in the city including building walls, roofs, roads should be made more reflective and less absorptive through various methods like soft landscaping, green roofs, shading of roads by avenue trees etc.

If solar gains in a building are reduced, thermal infrared radiations of the building blocks also reduce, thus alleviating the UHI effect locally and collectively at the town level.

Green cover should be introduced at all scales vis-a-vis., Building level, Urban scale, Neighbourhood scale, Community level, Meso level and Town/ City level.

Few Architectural and Urban Design interventions are as follows:

5.1. At Building Level

5.1.1. Treatment of the Openings

- Sunshades act as barriers to solar gains on the building exterior surfaces. Sunshades should be detached from the building surfaces so that Sunshades will not exchange the heat to the building through conduction gains.

- Especially in tropical zones, all the openings in a building should be guarded by Fins/Brise-soleils/ louvers etc. Vertical elements should be provided on the North/ South facades and on East/ West facades with

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Horizontal elements. These will be effective in shading all the openings, thus reducing solar heat gains. Egg-crate windows are also effective in this regard.

5.1.2. Walls

- The building façades should have projections on the exterior walls which will provide shade on the exterior surface of the building so that the building remains cool.
- Insulating the exterior walls or providing a second skin for the buildings helps in reducing solar gains which in turn protects the inhabitants from the ill effects of UHIs.
- Vertical landscape/ hanging gardens/ creepers on walls which will cover the whole surface will provide a better insulation to walls and reduces the temperature indoors by $3^\circ C - 13^\circ C$ [10]. These will replace the green cover of the urban areas which are lost in urbanisation. These also contribute to CO$_2$ absorption, and other air pollutants absorption, reduces noise pollution and increase the green cover of the urban areas.

5.1.3. Roofs

- Double roofs provide a good shade and insulation to the whole building thus keeping their occupants protected from the heat related problems indoors.
- Water ponds on the roofs also reduce the temperature indoors by $3^\circ C$ to $4^\circ C$ [12]
- Green roofs also reduce indoor temperatures by $4^\circ C$ to $6^\circ C$. These replace the Urban fabric with green cover, which provide O$_2$, absorb CO$_2$ and other pollutant gases, reduce noise indoors near Railway tracks and Airports etc. These will also prolong the life of the roofs [13].
- Roof tops can be painted white to reflect 90% sunlight so that the interior remain cool. White paints can reduce rooftop temperatures up to 20% or $5^\circ C$[14], [15]
- In tropical regions, glare is also an issue, buildings can be covered with shade nets/ garden netting which will allow diffused light, and reduces solar gains to the building [16].

5.1.4. Site Level

- Use of Passive Cooling techniques in buildings should be encouraged by governmental policies such as fiscal benefits etc.
  - Techniques like sub-terrain cooling
  - Ground coupled heat exchanger
  - Cooling pipes in the slabs etc.
- Green strips should be made mandatory around the buildings in the set-backs of area more than 200 Sq. M.
- Big canopy while large foliage shading trees should be provided in the periphery while on the west and south sides tall trees should be planted for proper shading.

5.2. Urban Design Level

- Dark coloured exterior walls should be avoided to reduce thermal gains.
- Urban Squares/ Spaces/ Streets with more pedestrian traffic should be covered with fabric/ canopy to protect surfaces and pedestrians from direct solar radiations.
- The pavements should be pervious to facilitate infiltration and grass/ turf etc. to reduce hard surfaces.
- Urban geometry should be analysed for proper wind channelization so that smoke, trapped warm air should be adequately ventilated.
- Orientation of the buildings should be analysed for winds and solar considerations.
- Street plantations should be managed by ULBs.
• Urban squares and public places should have cooling facilities like fountains, water bodies etc.

5.3. Neighbourhood Level

• Parks should be incorporated in each neighbourhood with foliage trees and water bodies.
• Low income group neighbourhood should be taken up on priority basis as, according to a study, Low-income neighbourhoods tend to have significantly fewer trees than neighbourhoods with higher incomes. They described this unequal distribution of trees as a demand for “luxury,” rather than “necessity”[17].
• Where parks are already available, their maintenance has to be taken up by ULBs and community participation.

5.4. Community Level

Parks and landscaping at community level has to constructed in open places, water bodies are to be accommodated and maintained.

5.5. Meso & Town Level

• Large lakes, water bodies, central parks act as heat sinks, if already available should be maintained properly, if not new open places should be allotted for water bodies and parks.
• Catchment areas should be clear of obstructions and impervious surfaces.
• Avenue plantations on collector and arterial roads are to be taken so as to shade the black top roads which act as heat absorbers in day time and emitters at night time. As roads contribute to about 35% to 40% land area in most of the cities.
• Fiscal (Short term) benefits are to be considered for adaptation of UHI mitigation policies in Urban areas.

6. CONCLUSION

The recommendations given in the paper have benefits at a larger extent towards mitigating the UHIs and in turn reduce thermal stresses on the urban dwellers and the inhabitants. But these are limited to Architectural and Urban Structural elements of the city whereas, other interventions like transportation, industrial sector have not been included here.

Governmental policies and ULBs can govern the development of new urbanism and retrofitting of the existing urban fabric with the given recommendations for reduction of effects and mitigating the UHIs. These interventions also help towards adaptation to Climate Change and in long run mitigate the impacts of Climate Change.

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