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An Urban Built Form and its Microclimate on Urban Heat Island

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ABSTRACT

Many elements, such as meteorological factors and city features, contribute to the establishment of urban heat islands. The city parameters, such as low albedo materials, urban geometry, high density, anthropogenic heat, and the like, are the most important factors that are responsible for the formation of it. Urban climate is becoming a complex issue locally and globally. There are many variables such as built environment, design model, urban morphology, density, vegetation cover, building height, orientation, distance between buildings, amount of sunlight on the road surface, wind direction, etc. Street-level velocities play a role in creating the city's thermal microclimate. This paper reviews previously published studies in this paper on the shape of built-up urban morphology and its microclimate on urban heat islands.

Keywords: *Street Canyon, Sky View Factor, Urban Microclimate, Urban Heat Island.*

Introduction

Cities are the engines of growth, owing mostly to the expansion of borders caused by demographic, economic, and infrastructure growth. Because of increased urban temperatures, these results differ in terms of microclimate. Many elements, including shape, shape, urban density, water level, and surface, impact the microclimate of a city open area (Shishegar, 2013). Oke's urban heat island parametric model indicated that increasing population density and urban temperature in city regions. There is a clear link between population expansion and the intensity of urban heat islands. An increase in the amount of energy used to heat and cool buildings (Oke, 1981).

Several studies on outdoor thermal comfort, urban canyon building heights with different objectives, and analysis methods have been carried out in many regions. For example, studies by Oke (1981), Bärring *et al.* (1985); Kusaka and Kimura (2004), Takebayashi and Moriyama (2012); Allegrini *et al.* (2012); Shishegar (2013), Dallman *et al.* (2014), (Gál, 2014); Haizhu *et al.* (2020), M'Saouri El Bat *et al.* (2020); (Mughal *et al.*, 2020).

The purpose of this work is to review the literature and current evidence on the morphology of urban buildings and on the geometric aspects of their microclimate. This white paper also focuses on out-

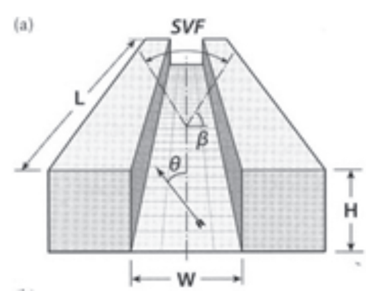

Fig. 1. L, B & H in the canyon and its SVF *Source:* (Das, 2013)

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door thermal comfort levels in road canyons, airflow and sun path, and their directional change in urban road canyons.

The Urban Street Canyon (Height/ Width (H/W Ratio)

Urban Street Canyon, usually a space formed by streets, sidewalks, or two parallel and vertical sections of infinite length separated by an open urban space. Shishegar (2013) climbed three types of road canyons in uniform road canyons, shallow road canyons, and deep road canyons. Based on the proportions of the wall openings, they are considered uniform canyons (aspect ratio = 1), a shallow street canyon (an aspect ratio < 0.5), and a deep street canyon (aspect ratio <0> 2). Leeward canyon walls are called leeward when they flow freely upward on the roof (Letzel *et al.*, 2008). Canyon Length (L) are the two main intersections that divide the driveway into short (L / H = 3), medium (L / H = 5) and long (L / H = 7) road distance between (Shishegar 2013). The following Figure 1 and 2 show a canyon on an urban road.

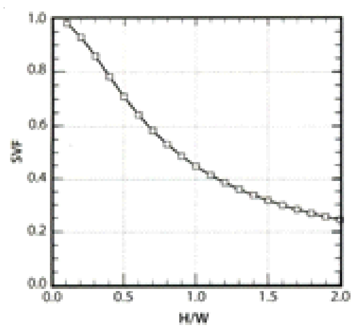


Fig. 2. Relationship of H/W & SV *Source:* (Das, 2013)

The impact of urban canyons on microclimate is discussed through research and studies. According to Oke's research, the urban canyon has a substantial impact on microclimate. By reflecting and absorbing heat, the canyon surface and vegetation begin a continuous heat transmission cycle. Due to the slower pace of 'urban' cooling after 'sunset,' the heat island intensity grows (Oke, 1981). In Malmo, Sweden, Bärring *et al.* (1985) investigated the relationship between the sky view factor and the thermal feature at night in urban canyons. Also, Bärring et al. (1985) discovered that street layout and its geographical distribution play a significant effect in the production of various temperature patterns in city streets. Building energy consumption for cooling and heating is influenced by the microclimate in street canyons, according to Allegrini *et al.* (2012) study. In the Mediterranean, Morgati *et al.* (2018) demonstrated the use of urban morphology indices for solar energy analysis. Ann Dallman *et al.* (2014) investigated the effects of resilience on heat circulation in urban canyon studies conducted under shifting environmental conditions. Ann Dallman described two scenarios, the first of which involved naturally heated walls that did not receive significant thermal assistance from the ground surface. In the second scenario, the temperature conditions in a 2D canyon were determined theoretically. Bakarman and Chang (2015) studied the thermal efficiency of two types of urban canyons in Riyadh, Saudi Arabia's hot and arid climate: deep traditional canyons with a H/W ratio of 2 and shallow modern canyons with a H/W ratio of 0.42. Further investigation revealed that parameters such as roadway orientation (NS-SW) and the H/W ratio inside the canyon influence ambient air temperature (Bakarman and Chang, 2015). Bakarman and Chang (2015) discovered that the intensity of UHI increases as the H/W ratio decreases in this investigation. The ambient air temperature is 5% warmer, and the shallow canyons are 15% warmer than the surrounding countryside.

Urban Canyon Wind Flow

Wind flow in urban canyons must be studied in order to disperse heat and pollution. The wind flow is determined by the urban design and street arrangement. In an urban canyon, wind speed and direction are additional important factors to consider. Vegetation, building height, shape, size, and scale of the building and openings, and wind direction are all

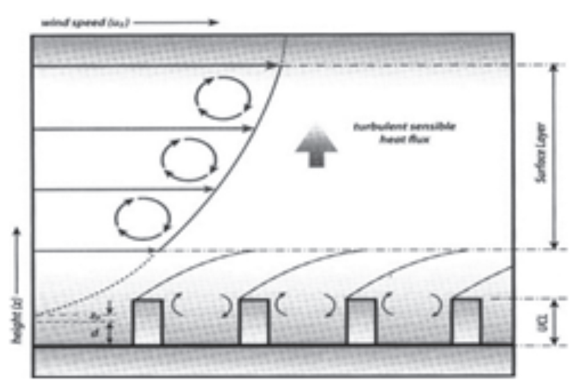
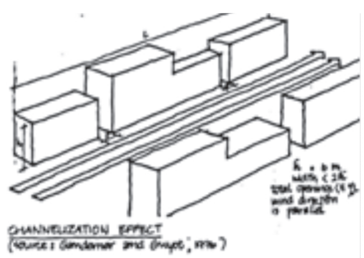


Fig. 3. The removal of sensible heat from a built-up urban surface by wind turbulence
Source: (Das, 2013)

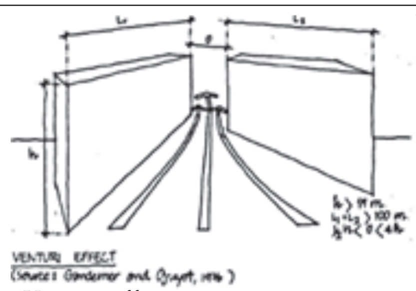
factors that affect wind flow, according to many studies. Figure 3 depicts the removal of sensible heat from a built-up urban surface by wind turbulence. As demonstrated in Figure 4, this may be understood using basic fluid dynamics principles such as channelisation, Venturi, and Bar effects.

Channelisation Effect: The wind moves in the same direction as the canyon, creating a channelisation effect that is ideal for flushing out impurities but difficult for users. The magnitude of this result is determined by the wind speed, as well as the canyon's overall span, average width, and average height (Das, 2013).

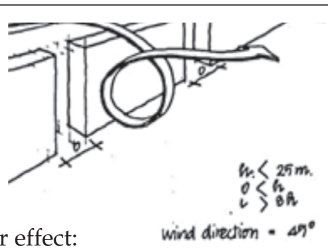
Venturi Effect: Wind speeds up when it passes through small openings, generating a funnel effect. Users may find this uncomfortable, yet it is a great method for dispersing pollutants. The breadth, length, height, and opening size of the canyon affect the degree of the Venturi effect (Das, 2013).



Channelisation effect:



Venturi effect:



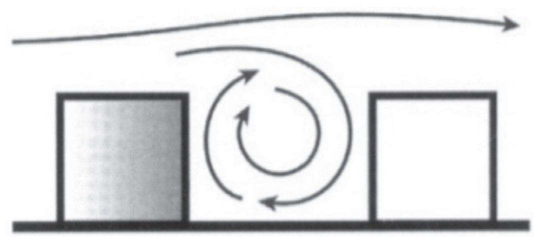
Bar effect:

Fig. 4. Effects of wind movement for dispersing heat and pollutants
Source: (Das, 2013)

Bar effect: The Bar effect is created when air rushes over a street canyon at a 45-degree angle on the other side (leeward). The width, length, and average height of the canyon's sides, as well as the size of the canyon's entrances, all influence this effect (Das, 2013). The aspect ratio can be used to distinguish between isolated roughness flow, wake interference flow, and skimming flow, as shown in Figure 5.

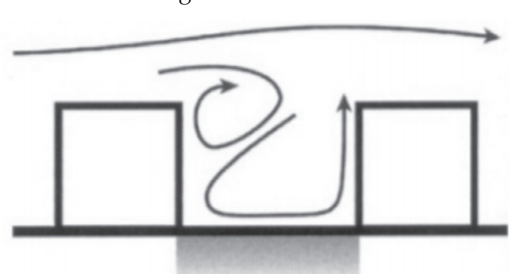
The isolated roughness rule applies when there is no contact between windward and leeward flows, probably due to a wind movement around an isolated barrier (Shishegar, 2013). Different roadway patterns, direction, geometry, building distances, vegetation, scale, wind speed, and location could all alter the airflow in the canopy layer. The diverse wind flow patterns are depicted in Figures 6, 7, and 8.

Sky View Factor (SVF) of Urban Street Canyons



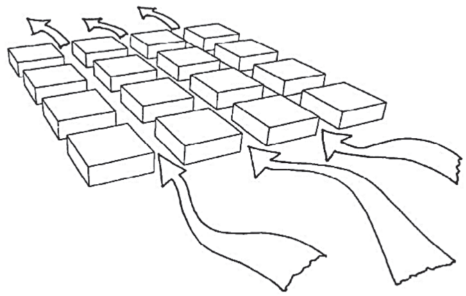
Leeward Heating

Windward Heating

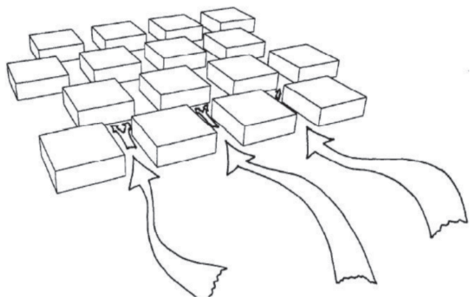


Floor Heating

Fig. 6. Wind Flow pattern based on heating at different sides of the canyon
Source: (Das, 2013)



Straight and parallel starts improve airflow into and within an urban area



Slow airflow movement due to Narrow and winding streets

Fig. 7. Street Design and orientation influence the design of wind penetration into the city
Source: (Das, 2013; Shishegar, 2013)

Wei *et al.* (2016) discovered that sky obstructions can delay ground cooling in clean, calm evenings (Wei *et al.,* 2016). For basic canyons, Oke claims that the height to breadth ratio is directly connected to the sky view factor (Oke, 1988). Oke offers a method for calculating the SVF by assuming the radiation geometry at a point in the middle of the canyon cross-section in Fig. 9. The ratio of the radiation received (or released) by a flat surface to the radiation emitted (or received) by the full hemispheric environment is known as the sky view factor (Wei *et al.,* 2016).

Wai *et al.,* (2016), on the other hand, investigated the impact of urban morphological characteristics on microclimate. To determine optimal parameter ranges that are helpful to the thermal comfort of urban pedestrians. In addition, Chen and Ng (2009) used a GIS-based methodology in Hong Kong to investigate SVF analyses of street canyons and their inference for UHI intensity.

Urban Density Parameters

Space-mate tool was established by Pont, M.B, inclusive density indicators figure to characterise urban

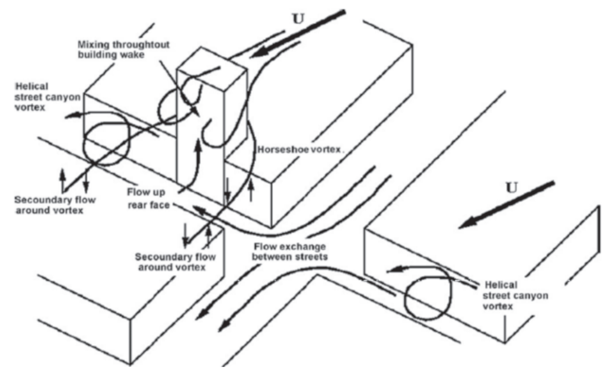


Fig. 8. Wind Flow pattern at the street node with varying shape, size, and height of a building *Source*: (Shishegar, 2013)

geometry as described in Figure 10. It is possible to define an urban environment by a set of density variables such as floor surface index (FSI), ground space index (GSI), the open space ratio (OSR), and layers (L). These quantities can be used both to describe, characterise and prescribe different urban environments. The FSI, GSI, OSR, and L are comprised in 'space-mate' have to be presented to validate how the geometry of a site can be distinguished from others. Hu *et al.,* (2016); Wei *et al.,* (2016); Bagan *et al.,* (2018); Kim and Guldmann (2014); Singh and Singh, (2018) out of many more researcher this are some of them who have evaluated the impacts of urban density on urban heat.

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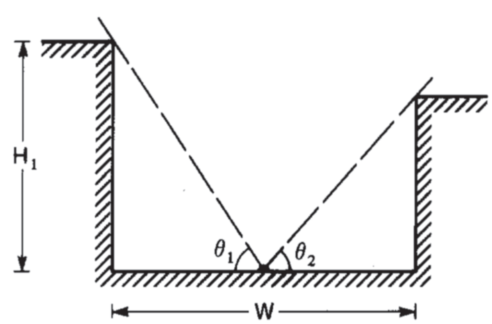

Fig. 9. Geometry of an unsymmetric canyon flanked by buildings 1 and 2 *Source:* (Oke, 1988)

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Conclusion

The effects of urbanisation on microclimate and characteristics of urban microclimate were explored in this research. A complete environmental design method for street design is dependent on or changed by changes in built form geometry. Airflow and sun view parameters are influenced by the street geometry (H/W and L/W ratios) and its geometry. The H/W, L/W, and density (building occupancy) ratios all play a role in raising or diminishing the UHI effect. For the urban canyon to receive maximum shadowing, the influential orientation of urban streets should be north/south, northeast/ southwest, and northwest/ southeast. Wind flow canyons of urban roadways imply that the sky view factor (SVF) increases ground level openness, and that random arrangement is better than uniform layout, and that horizontal unpredictability is more relevant than vertical randomness.

A healthy microclimate in an urban area and an urban canyon should be planned to provide everyone with enough access to sunlight and wind. As a result, energy consumption and the urban heat island effect will be reduced.

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