THERMAL COMFORT IN PUBLIC SPACES: A CASE OF CONNAUGHT PLACE, NEW DELHI

Ar. Kamini Singh
Architect, Urban Designer
PhD Research Scholar
Dept. of Urban Design, SPA,
New Delhi, India
kamini196phd18@spa.ac.in

Ar. Mandeep Singh
Architect, Urban Designer
Member, Delhi Urban Art Commission
New Delhi, India
mandeepspa@gmail.com

ABSTRACT

This research identifies and evaluates the local climatic zones in streets and plaza spaces of Connaught Place, New Delhi to analyse the space-form-activity relation. The phenomenon being studied here is the variation in micro-climatic conditions because of changing urban form, material, natural features and anthropogenic heat sources. The paper is built on the hypothesis that there is an impact of spatial form and elements on microclimate which further influence the user perception of thermal comfort and hence, the activities in public spaces. The quantitative data of microclimatic parameters is overlaid upon the human activity levels. This is done by collecting primary data for ambient temperature, surface temperature, humidity, wind velocity and CO2 levels for the selected ten spots in Connaught Place. The variation in the data is then analysed for underlying causes and whether it is related to the physical properties of that space. The selected physical properties are layout, height-width ratio, surface materials, orientation, amount, and the type of vegetation. The results show a significant variation in spot level micro-climatic data within a spatial boundary of 1.5 kilometre of study area.

Keywords: *Public spaces, urban climates, thermal comfort, urban surfaces, Connaught Place*

1. INTRODUCTION

Global warming is likely to reach 1.5ºC between 2030 and 2052 if it continues to increase at the current rate (IPCC, 2018). The rise in global temperatures and changing patterns of climate is first witnessed in urban centres which are the generators and major cause of heat island and temperature inversions. Although no single field of study can deal with the issue, yet the role of built environment cannot be ignored. The city centres which are often public spaces have been found to show higher temperature than the urban periphery. When the public spaces become uncomfortable for users, the preference for indoor air-conditioned spaces increases and further contribute to anthropogenic heating of outdoors. People are forced to follow a lifestyle that is energy-intensive and is active in artificial environments.

The vibrancy of outdoor public spaces is determined by the number of people actively using that space. In outdoor environments, people prefer sunny places in winters, shade from extreme radiations in summer, to enjoy spring breeze and places next to water in hot-dry climates. Comfort can be thought of as the balance between relaxation and stimulation. . . When we enter a space, we perceive it through our senses. Sensory stimuli cause emotional arousal, which can lead to psychological and physiological responses of comfort or discomfort (Huss, 2016). The study of urban comfort must deal with the comfort of people in urban public spaces where it is seen as a collective cultural and climatic attribute. The cultural practices enable users to adapt to extreme climatic conditions, aspects of everyday life, activities and rituals. Hence, it is suitable to call it as 'achievement rather than attribute' (Tavares, 2015). The human response to climate is either through clothing, increase or decrease in activity, gathering in sunny or shaded areas, or in extreme cases choosing an indoor space for social interaction. When outdoor spaces are more comfortable for user there is greater activity contributing to the success of a public space.

2. CONNAUGHT PLACE, NEW DELHI

2.1 Context

The city of Delhi lies in the composite climatic zone with climate ranging from 47ºC on summer afternoons to 2ºC on winter mornings. Connaught Place, at the low-density core zone of the city of Delhi, has central ridge greens on left and the River Yamuna on right side, both within 5km distance. It is considered to be the city centre of the capital, Delhi as envisaged by Lutyens, the architect of New Delhi. The metro station is the busiest in the city with a footfall of 5 lakh passengers per day (DUAC, 2018). From the primary survey it was found that about 71% of visitors use the metro to reach Connaught Place. It attracts men and women of varied age groups equally and the most popular purpose of the visit is eating, shopping and meeting family and friends. 62% of people who participated in the survey visit monthly. The most popular time to visit is between 2:00 – 6:00 pm except during summer months when there are greater number of visitors after 6:00 or later. It is the most popular public place in the city and attracts varied age groups, genders and activities. However, in a study conducted by the Centre for Atmospheric Sciences, Indian Institute of Technology, Delhi (Mohan, 2009), it was among the warmest pockets in the entire study area i.e., the Connaught Place- Sitaram Bazar zone. This pocket not only has the highest urban heat island (UHI) but also covers the largest area in comparison to other pockets on all days.

3. METHODOLOGY

A study of physical characteristics was done through photography, mapping and architectural drawings for selection of key spots. This was followed by a user survey to understand general user perception of space with 53 participants (29 males and 24 females) of varied age, gender and economic status. Micro-climatic data was collected with Testo 174 H Mini Data Logger for temperature and humidity and Testo 480 Multi-Function HVAC Meter for spot-level temperature, humidity, wind velocity and CO2. Testo 872 IR Image camera was used for thermal imaging. The data was collected for a duration of three days (22-24 November 2019) at three intervals (12 am, 2 pm and 4 pm). The spots selected are shown in Figure 1.

3.1 Research parameters:

i) Canyon Aspect ratio & Shading: Since building blocks create an urban canyon that collects heat, height to width (H/W) ratio has an influence on heat mitigation by shaping the canyon for wind distribution and street shading (Takkanon, 2016). The inner circle street has a shaded arcaded pathway running parallel to the buildings, with trees at occasional spaces (H/W ratio =1). The middle circle street in between does not have any arcade or trees, but due to the high street canyon (H/W ratio =1.6), there is mutual shading by buildings for most of the day. The outer circle has double-height arcades and varying building heights of 4 to 86 metres on the opposite side. The H/W ratio varies from 0.175 to 1. The streets radiating from the inner circle to outer circles have pathways shaded by arcades along the edge of buildings and the H/W ratio of the street canyon varies from 0.5 to 0.3.

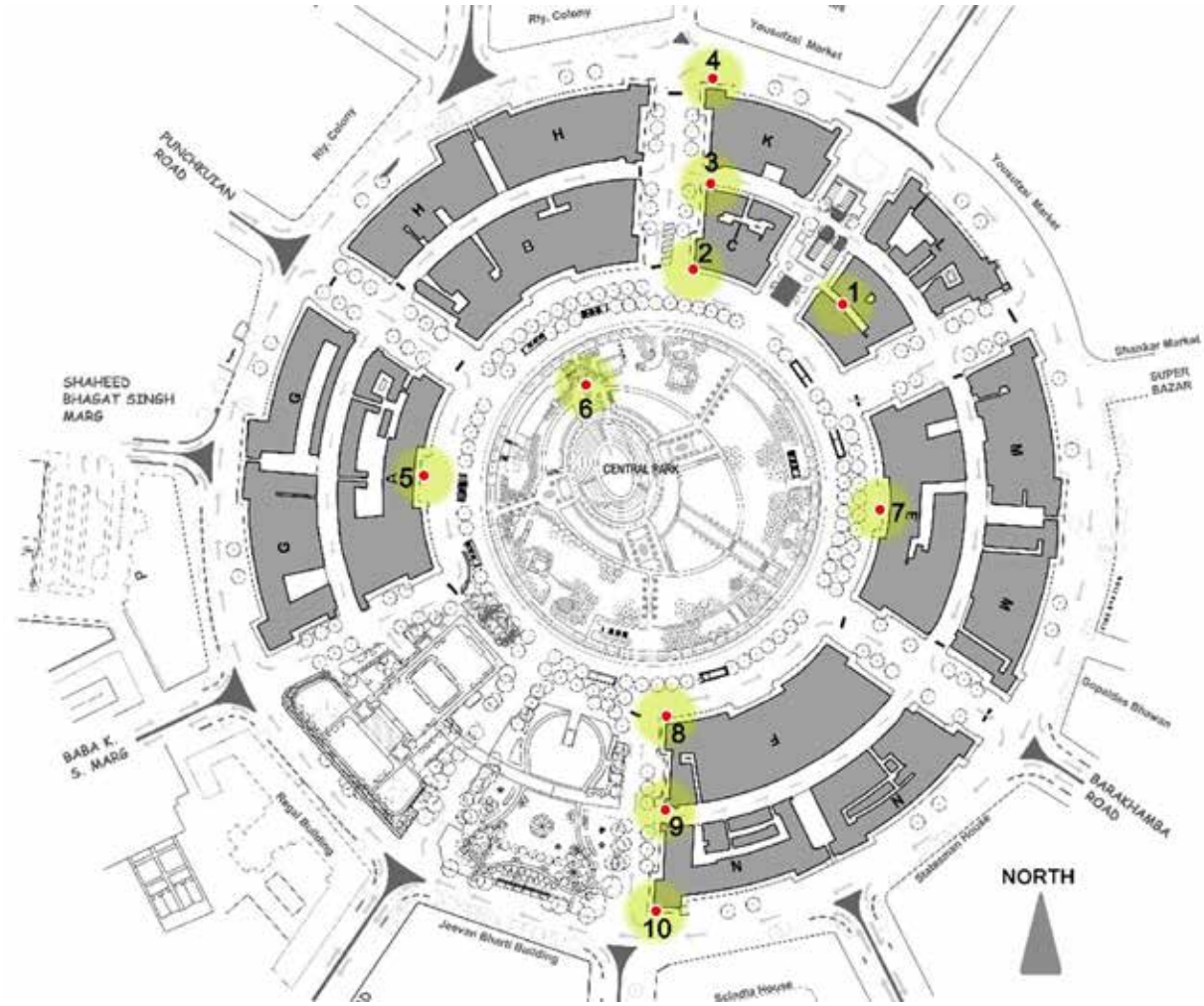


Figure 1: Map showing spots selected for climatic data collection
(Source: Author)

ii) Orientation: Due to the circular layout and identical buildings, the site provides an opportunity to evaluate the diurnal influence of changing orientation. The circular layout added issues in perceiving the location and way-finding as identified during user survey by 54% of the respondents.

iii) Vegetation: The site is sparsely vegetated with planters at regular interval and few large trees with dense foliage along inner and outer circle streets. The large lawns of central park have greater variety and combination of shrubs, decorative plants and large trees (on the eastern side only due to underground metro).

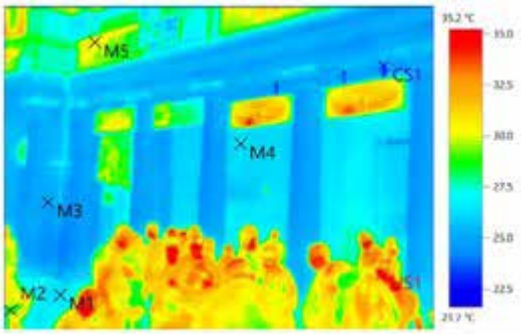
iv) Street Furniture: The site has three types of seating facilities – seating with granite stone cladding, circular and straight metal benches, and granite kerbstones and planter seat walls. Most of the amenities are in better condition in the inner circle while the middle circle lacks lighting in several spots and has no seating facility. The three critical issues according to the user survey were : (1) the number of seats (2) the area of sunny versus shaded walkable spaces (3) the quality of public toilets. Most of the public toilets are at the middle circle and were poorly maintained. 60% of the women were not satisfied with the public toilets while men had a lower percentage (46%) of dissatisfaction with public toilets.

v) Materials: The building façade is primarily made up of brickwork with lime and cement mortar with white cement plaster (originally lime plaster) which keeps the façade cooler. The metal signage with lights, air-conditioning units etc. cover part of the façade and are 6 degrees warmer in November as compared to the white plastered surface (Figure 2). The material of paving on pathways includes black granite, red sandstone, and interlocking pavers (Figure 3). The vehicular road is made up of black asphalt with cobblestones for table-top pedestrian crossing.

vi) Urban micro-climate: According to the Safdurjung Weather Station data for survey dates, the maximum temperature at 2:00 pm was 26.1ºC. The hourly average wind direction was west (40%), north (37%), east (15%), and south (8%) and average wind speed was 5.8 miles per hour (the windiest time of day was at 2:15 PM) (Retrospective, 2019).

4. RESULTS

The spot-wise primary data of the selected ten spots was as shown in Figure 4. The spot-wise microclimatic data was utilized to calculate thermo-physiological significant index of physiologically equivalent temperature (PET) using the Rayman model. Further spatio-physical characteristics were evaluated for each spot where in the

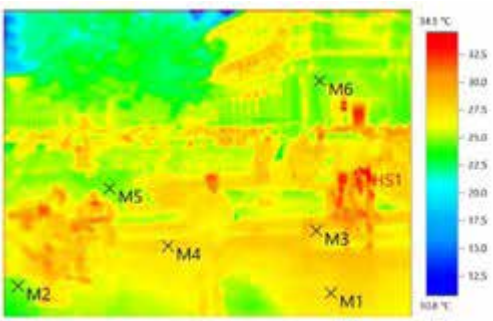


Picture data:	**Date:**	24-11-2019	**Emissivity:**	0.95
	Time:	14:13:28	**Refl. temp. [*C]:**	20.0
	File:	SR001136.BMT		

Picture markings:

Measurement Objects	Temp. [*C]	Emiss.	Refl. temp. [*C]	Remarks
Measure point 1	26.1	0.95	20.0	pedestrian pathway
Measure point 2	28.2	0.95	20.0	SS bench
Measure point 3	24.8	0.95	20.0	Building facade - white plaster
Measure point 4	26.1	0.95	20.0	building facade - shaded in arcade
Measure point 5	30.3	0.95	20.0	signage board - metal
Cold spot 1	21.7	0.95	20.0	metal - shaded
Hot spot 1	35.2	0.95	20.0	human

Figure 2: Thermal image of vertical surfaces at spot no. 7
(Source: Author)



20.0

Picture data:	**Date:**	24-11-2019	**Emissivity:**	
	Time:	14:13:28	**Refl. temp. [*C]:**	
	File:	SR001209.BMT		

Picture markings:

Measurement Objects	Temp. [*C]	Emiss.	Refl. temp. [*C]	Remarks
Measure point 1	26.5	0.95	20.0	Paving
Measure point 2	23.9	0.95	20.0	Seating
Measure point 3	27.5	0.95	20.0	Seating
Measure point 4	26.9	0.95	20.0	kerb
Measure point 5	23.8	0.95	20.0	plants
Measure point 6	23.9	0.95	20.0	building facade - plaster
Hot spot 1	34.5	0.95	20.0	Auto riksaw

Figure 3: Data from thermal image of horizontal surfaces at spot no. 2
(Source: Author)

thermal images were overlayed on architectural drawings to explore the relation between spatial orientation, surface temperatures, spatial enclosure (calculated by H/W ratio of the street canyon) and the presence of vegetation. The relation thus understood was evaluated to understand the user-thermal comfort through PET and activity at each spot. The results are compared and analysed in Table 1 below. The colour coding denotes actual surface temperature recorded as per scale in spot 1.

The temperature data showed maximum variation of 2.7ºC at 12:00 AM. The least variation in temperature was recorded at 4:00 PM of 1.8ºC. Lower temperatures were recorded on the spots located on north-south orientation, high vegetation and shade. Higher temperatures were recorded on spots with greater building enclosure, low vegetation and facing south and west. Humidity increases by evening in all the selected spots. However, the maximum variation was only 6 % due to dry season. Also, humidity data shows inverse co-relation with temperature. Wind velocity has a close co-relation with the enclosure and orientation. Spaces located at building corners and junctions show greater wind velocity. Open space in the central park (negligible enclosure at spot 5) and space enclosed from all four sides (maximum enclosure at spot 1) show negligible wind velocity. Also, hazardous CO2 levels were recorded due to anthropogenic heat produced from vehicles and outdoor unites of air-conditioners. A greater wind velocity results in lower CO_2 levels.

Key observations

- Spots oriented towards east were less active till mid-day as the early sun exposure kept the surfaces warm till 2:00 pm. The spot facing west remains comfortable till 2:00 pm and had high activities till mid-day.
- Trees with dense foliage had the greatest impact on micro-climate. The shadows cast reduce the surface temperatures, maintains humidity levels and wind velocity, and lower CO2 levels

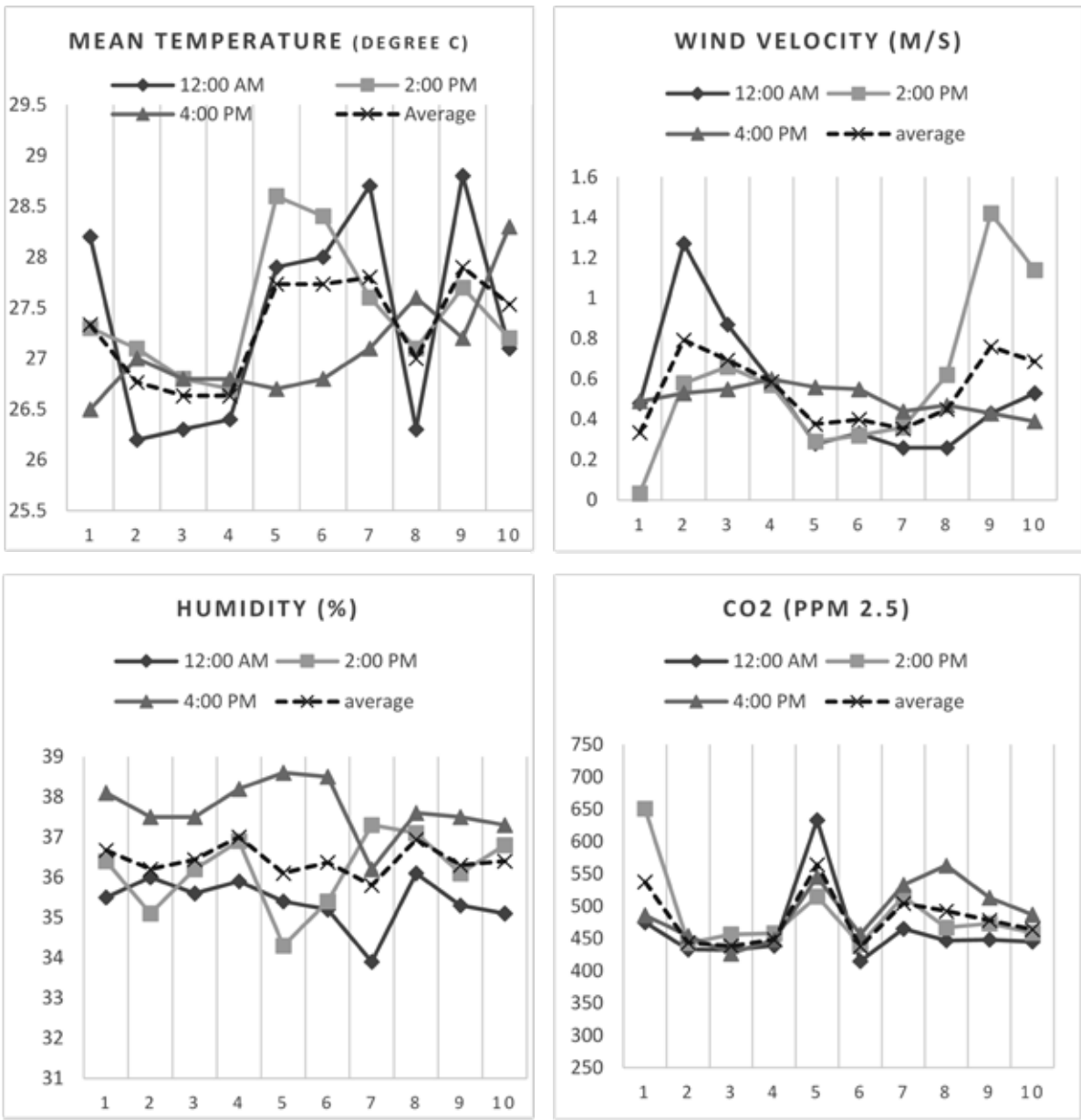
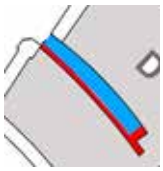
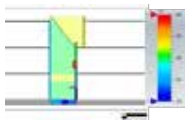
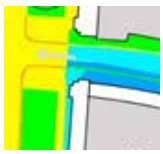
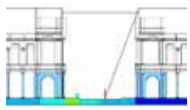
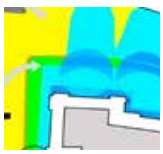
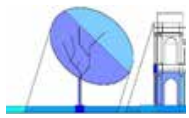
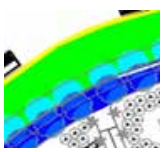
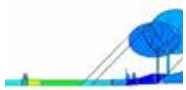
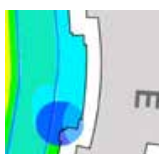
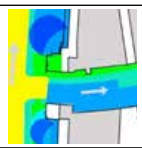


Figure 4: Comparative graph of temperature, humidity, wind velocity and CO2 data for ten spots at Connaught Place, New Delhi (22-24 November 2019) *(Source: Author)*

Table 5: **Analysis of different hues of colour**
(Source: Author)

Spot No	Orien-tation	Plan form& surface temperature	H/W ratio	Section showing surface temperature	Space type	Shading	PET	Inference
1	NE & SW		2.5		Inner Lane	Adjoining building Shadow	27.3	• 3 side enclosure lowest H/W ratio, lack of openings in the built mass causes negligible wind velocity results is average PET • The overall Impact of AC Outdoor units, kitchen emissions and Low wind velocity account for very high level of CO2.
2	South Facing		0.5		Plaza	Arcade, trees	26.8	• Southern orientation, high wind velocity, shaded with dense tree foliage cause low PET & low CO2 levels. • High human activity – Arcade, Plaza, and seating spaces with a combination of sunny and shaded areas.
3	North facing		1.25		street	Building shadow till noon	26.6	• Inner circle with northern orientation, high H/W ratio and cross-junction cause for canyon effect and greater wind velocity. • Lowest PET value and CO2 levels
4	North facing		0.3		Parking Plaza	Peepal (Azadirachta Indica) tree, Building Shadow	26.6	• Outer circle with Northern Orientation, high vehicular activity and large dense foliage of Ficus religiosa cause high wind velocity and shading • Lowest PET value and CO2 levels
5	North facing		0.05		Plaza	Evening Shadows, tall tree sparse foliage, Arcade	27.8	• Highest temperature till 2 pm, tall tree with sparse foliage lowest wind velocity and highest CO2 • High PET value and low activity levels till midday.
6	Open to air		0.01		Park	Trees, grass cover, water body	27.7	• High temperature till 2 PM, and low temperatures by evening cause for high human activity in the evening. • Green cover and patches of dence plantation, low antrhopogenic heat and low CO2 levels
7	West facing		0.05		Plaza	Morning Shadows, Tree with sparse foliage	27.5	• Western orientation with partial enclosure, constant temperature, low wind velocity and CO2 levels throughout day. • Average PET Levels and comparatively active spot due to low solar radiations
8	North facing		0.35		Street	Directly below tree, Building shadow, arcade	27.1	• Very high CO2 levels by evening time due to greater vehicular movement. •Low PET levels low wind velocity due to north facing façade and dense trees • High activity comprising of predominantly male users.
9	South facing		1.25		Street	Adjoining building Shadow	27.6	• Average PET levels due to greater enclosure and cross-junction • Only vehicular movement and moderate CO2 levels
10	South facing		0.41		Plaza	none	28.4	• Highest PET value & low CO2 levels • Pedestrian plaza at the Traffic junction crossing. Least comfortable spot- high surface temperatures, glare, empty seating, transitory space.

- Higher wind velocity near corners and in street canyons, low in plazas enclosed on three sides.
- North-south orientations are better for pedestrian comfort levels and were seen to be more active.
- The vertical surfaces plastered white were cooler than the ambient temperature of the spot.
- The glossy-reflective, dark coloured granite stone paving and had higher surface temperature (31ºC) than the ambient temperature in sun and in shade it was 2-3 degrees lower (24ºC) than the ambient temperature.
- The horizontal road surfaces with asphalt have high temperatures ranging from 28ºC in shade and 30ºC in solar-exposed condition.

5. CONCLUSION

The site appears to have a strong symmetry and uniformity in terms of built form and material. The space which appears uniform in terms of architecture, have been found to have local climatic zones of varying comfort range. When the spot level micro-climatic data was compared to the city level metrological data the variation in temperature was within a range of 3 to 4ºC. The individual spots show very high variation in terms of humidity up to 5%, wind velocity up to 1.3m/s, CO2 levels up to 200 ppm 2.5 and surface temperatures ranging from 3ºC (air-conditioned spaces with glass) to 100ºC (motor vehicles) due to the three-dimensional physical form, orientation, shading, materials used on outdoor spaces and the anthropogenic heat produced due to human activities such as vehicular emissions. This greatly impacts the comfort characteristics of the space and sub-conscious user perception about the comfort levels of the space. This eventually affects the quality of an urban space and its place-making characteristic.

REFERENCES

1. DUAC. (2018). Pedestrianisation of Connaught Place. Delhi: Delhi Urban Art Commission. Retrieved from http://duac.org.in/Upload/City%20Level%20Studies/Transport%20studies/653965875707532.pdf on 20 June 2021.

2. Huss, S. (2016). Measuring Human Experience of Public Spaces: A Methodology in the Making, Conscious Cities.

3. IPCC, I. P. (2018). Global warming of 1.5-degree C. Switzerland: IPCC. Retrieved from https://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf on 10 August 2019.

4. Mohan, M. (2009). Assessment of Urban Heat Island Intensities over Delhi. The Seventh International Conference on Urban Climate. Yokohama, Japan.

5. Retrospective, N. s.-M.-2.-E. (2019). Weartherspark.com. Retrieved from https://weatherspark.com/d/109174/11/22/Average-Weather-on-November-22-in-New-Delhi-India#Sections-Temperature on 23 November 2019.

6. Takkanon, P. (2016). A Study of Height to Width Ratios and Urban Heat Island Intensity of Bangkok. Singapore. Retrieved from https://www.researchgate.net/publication/304023198_A_study_of_height_to_width_ratios_and_Urban_Heat_Island_Intensity_of_Bangkok on 20 June 2021.

7. Tavares, S. G. (2015). Urban comfort: adaptive capacity in post-earthquake Christchurch. Christchurch: Lincoln University.

Kamini Singh is a practising architect, urban designer and a faculty at Apeejay School of Architecture and Planning, Greater Noida. Her research interest lies in exploring the place-making potential of urban spaces. She has over nine years of professional experience in academia, research, and architectural practice.

Prof. Mandeep Singh has been Head, Architecture (2014-15 & 18-19), Dean of Studies (2015-17), Head, Urban Design (2011-14), Head, Industrial Design (2005-10), apart from being a full-time faculty at the School of Planning and Architecture, New Delhi from 1986 to 2021. In addition to teaching, guiding design and research projects for 35 years, Prof. Singh is currently serving in several committees set up by the Government of India.