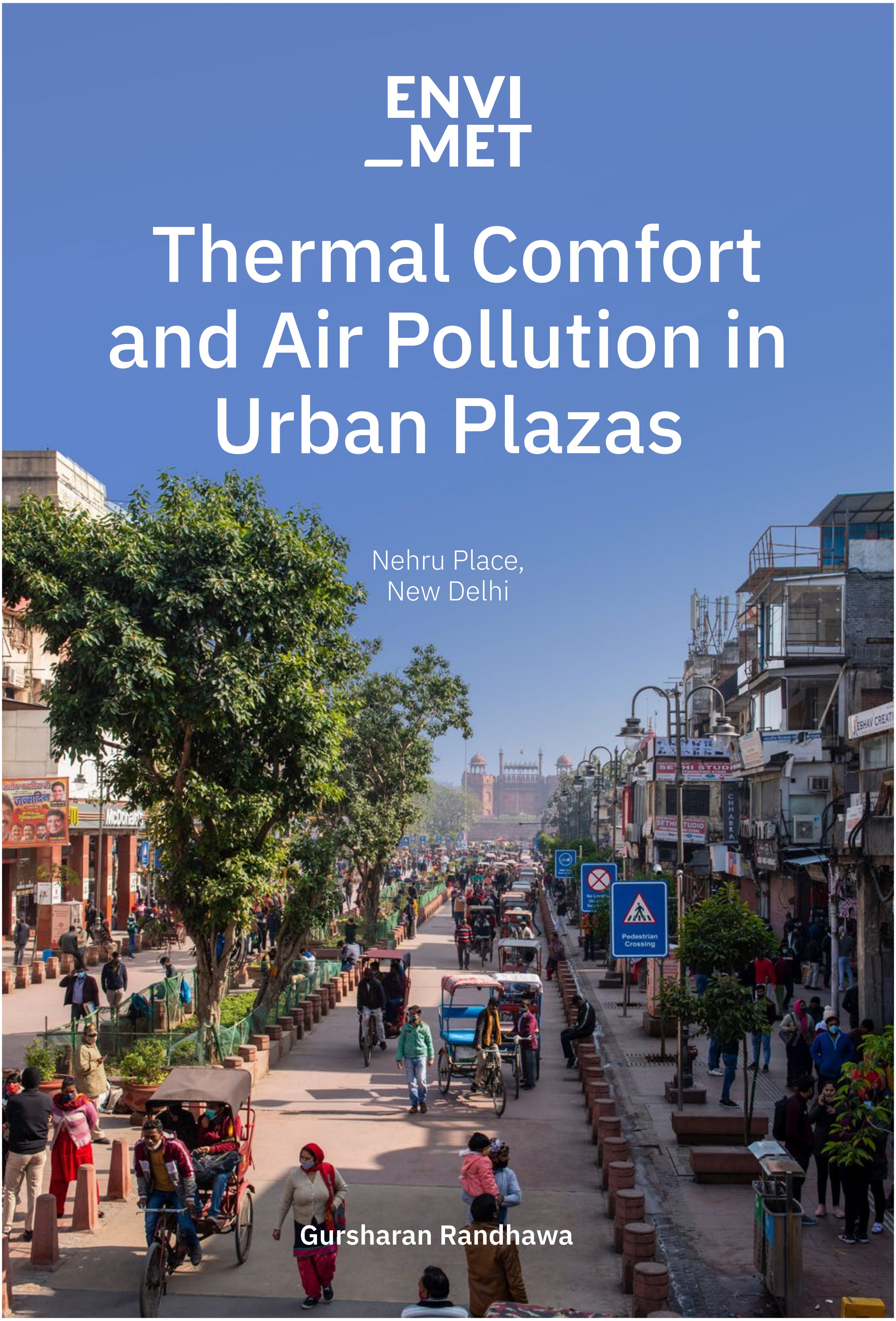
ENVI_MET

Thermal Comfort and Air Pollution in Urban Plazas

Nehru Place,
New Delhi

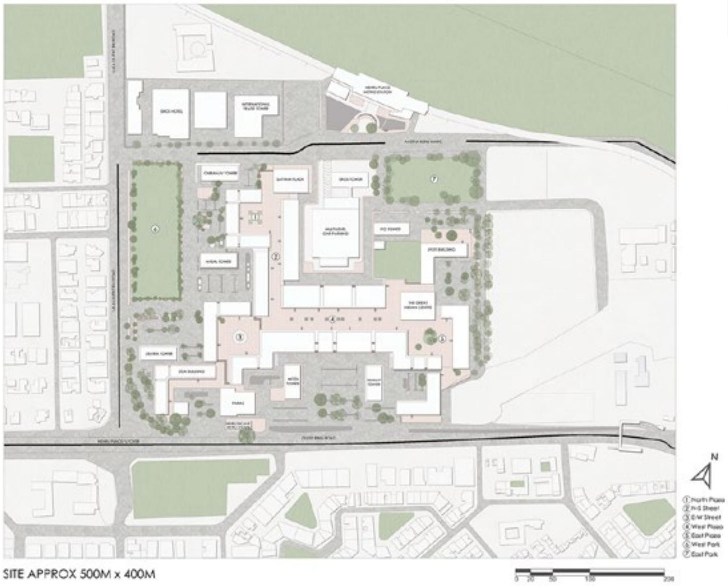


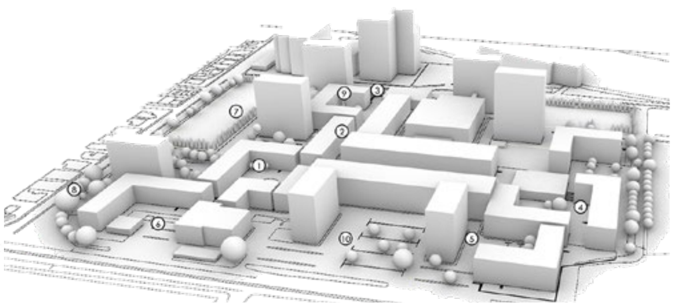
Gursharan Randhawa

Introduction

Strategies to improve Thermal Comfort and Air Pollution in urban plazas.

A study of District centres in New Delhi, India.





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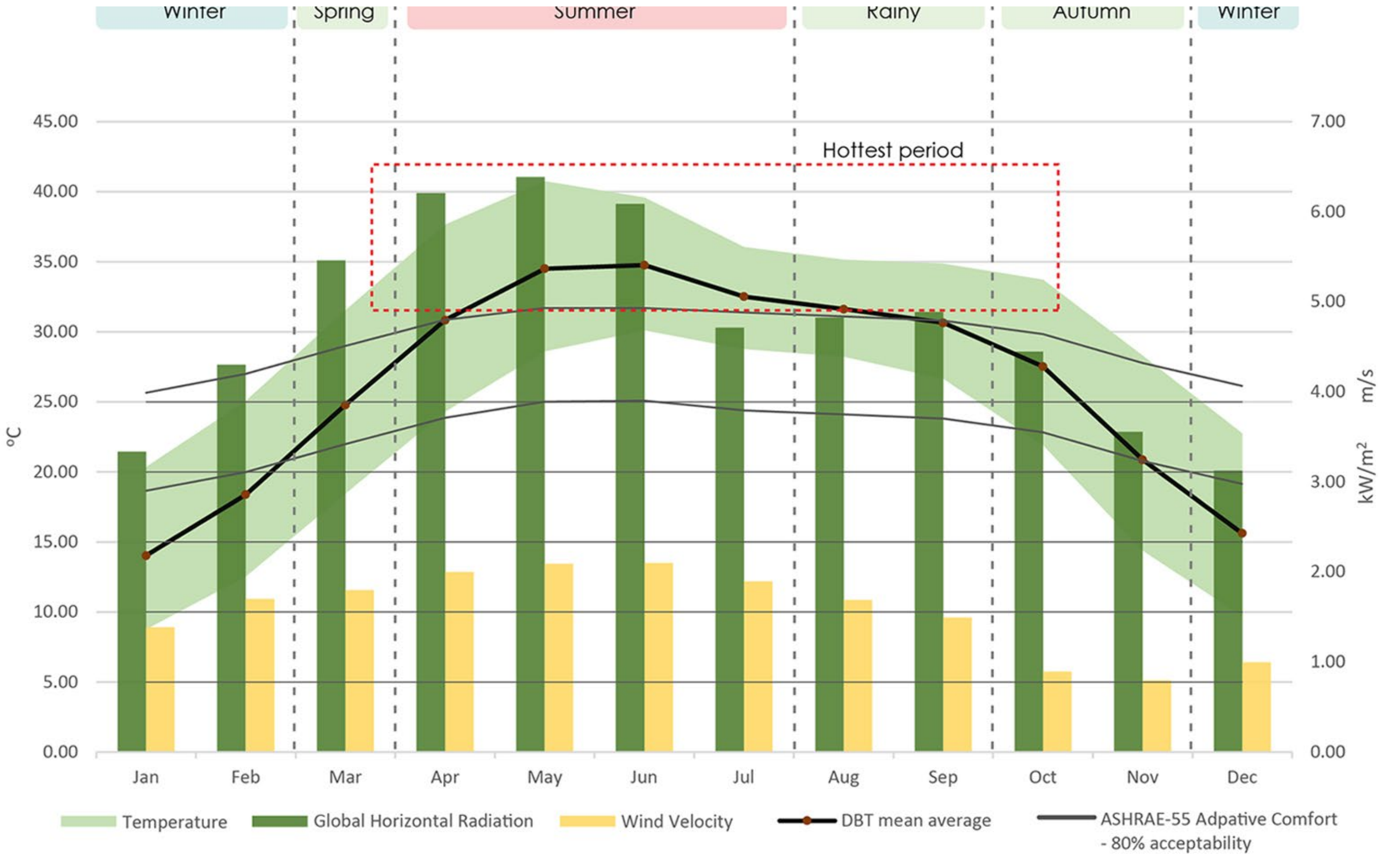
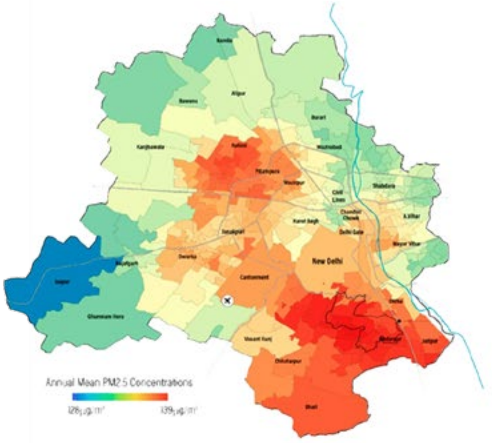
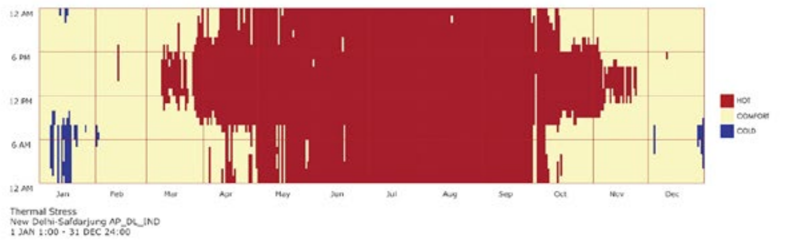
With the rapid rate of urbanisation, outdoor thermal comfort is a growing concern in dense city centres where the outdoor plazas and open spaces such as walkways, corridors and roofs, often used as a bridge or transition between two spaces, is often left neglected. These open spaces hold interactions between public and private, people and environment, inside and outside and often connect people and places but is in a sad state of environmental crisis. Air pollution has become a cause of worry in developing nations which has a direct impact on urban human health. In order to improve the understanding of microclimate and the impact of built environment on these open spaces, a detailed and accurate environmental study is needed for understanding urban thermal comfort. The statistics presented in the study are based for a typical urban setting in one of the 17 District centres in New Delhi utilising a variety of computational tools (ENVI-met, Rhino, Grasshopper). Typical summer conditions are considered as the base for worst case scenarios to investigate the potential impact of all the factors on outdoor thermal comfort. The strong impact of urban vegetation, pavement albedos and façade greening are highlighted. The findings of the base case will be helpful for urban spaces with similar morphological characteristics. The study concludes with a catalogue of possible interventions to mitigate urban thermal comfort in these transitional spaces of trade centres and ultimately achieve an environmentally conscious solution.

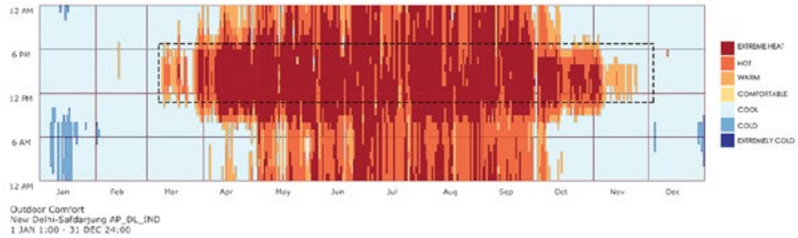


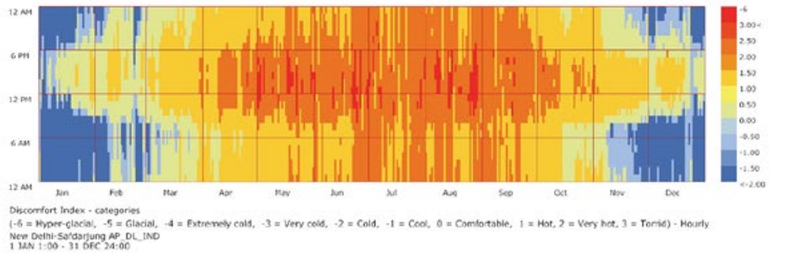
The climate of New Delhi is an imbricate of monsoon influenced humid subtropical (Koppean climatic classification Cwa) and semi-arid (Koppean climate classification BSh) with significant temperature and precipitation differences between summer and winter. The year is constituted with prolonged period of extremely hot weather with dust storms commonly referred to as loo and relatively dry short winters.

Due to the proximity of New Delhi to the Himalayan ranges on the North and North-east and Thar desert on the west, the landlocked region experiences 5 distinct seasons Summer, Autumn, Winter, Rainy and Spring with most of the Rainy season through monsoonal winds.







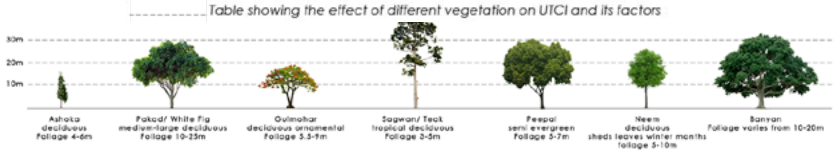


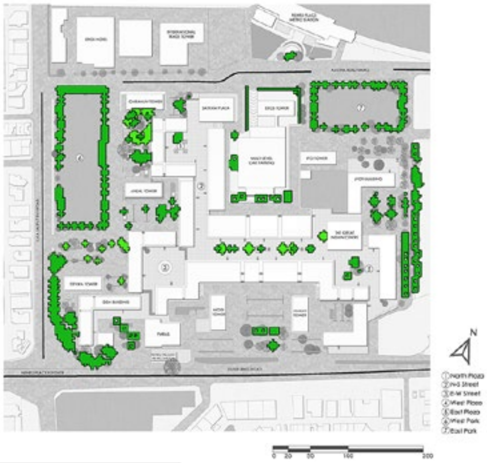
Specific to the city, transport, Dust and power plants are the primary contributors for over 50% of PM2.5 emissions. The concentrations of pollution are noticeable in the core of the city compared to its urban periphery due to extensive infrastructure projects and traffic congestions in the city. It is observed that over the years noticeable drops in PM2.5 levels are observed as a result of policy initiatives and clear air programmes taken up by the government. Another initiative taken up is the closing down of one of the many Thermal Power plants which are a main source of pollution in and around the national capital.

Existing vegetation conditions

Parameters	Outcomes	Observations	Local tree variants
Mean Radiant Temperature	Typology 1,5,6 (Medium trunk Cylindrical and Spherical trees)	Small and Medium height trees with medium trunk with low LAD performed best for MRT, low LAD ensured heat doesn't trap between the trees	Ashoka, Neem, Teak
Local wind speed	Typology 5,6,7 (Medium trunk, low LAD)	Trees with low LAD, small or medium trunk, allowed for local wind movement better than trees with dense foliage	Pakad tree, Peepal, Banyan
Relative humidity	Typology 5,6 (Medium trunk, low LAD)	-	Ashoka, Neem, Gulmohar
UTCI	Typology 5,6 (Medium trunk, low LAD)	Medium trunk trees with low LAD performed best under extreme weather conditions of Delhi, bringing the UTCI within moderate range (under 38°C) from extreme heat stress.	Ashoka, Neem, Gulmohar

Table showing the effect of different vegetation on UTCI and its factors





Surface		Emissivity	Albedo
Ground	Asphalt	0.95	0.125
	Grass	0.93	0.205
Facades	Brick	0.91	0.3
	Concrete	0.805	0.225
	Wood	0.9	0.15
	Stone	0.9	0.275
	Glass	0.895	0.305
	Tile	0.9	0.225
	Slate	0.9	0.1
	Corrugated iron	0.205	0.13
Roofs	Tar roof	0.92	0.13
Natural	Forests	0.97	0.15
	Water	0.97	0.5

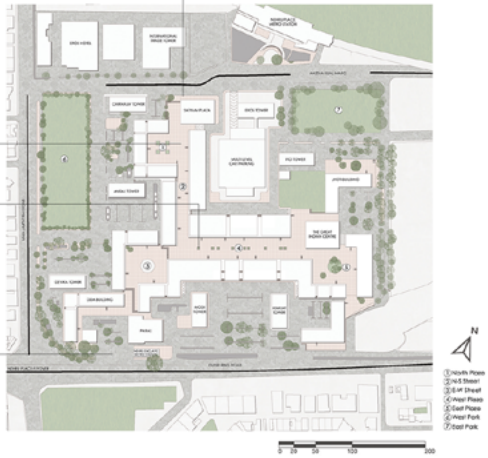

Pavements and Parking

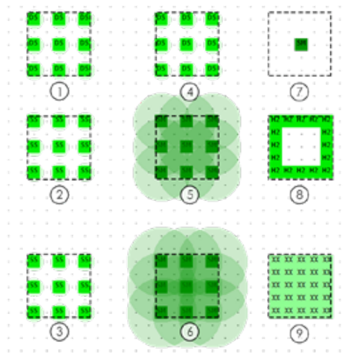

Main plaza

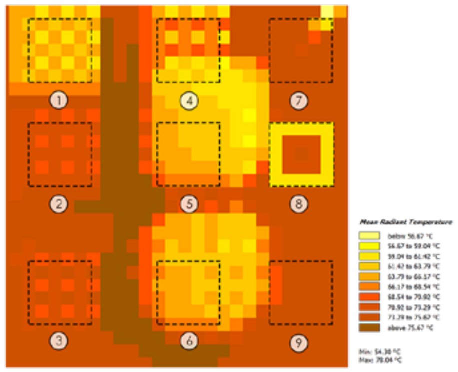

Concrete Facades throughout the site

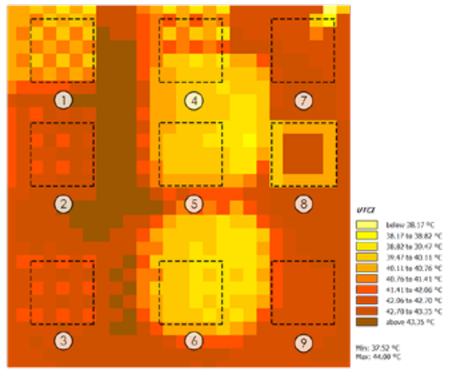

Around trees

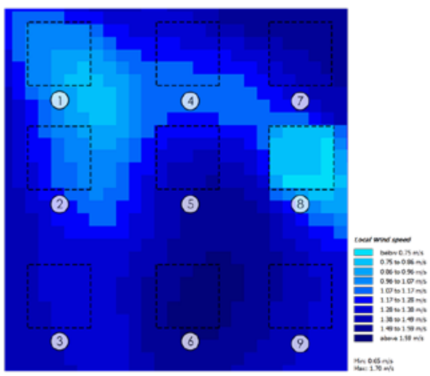

Asphalt Roads

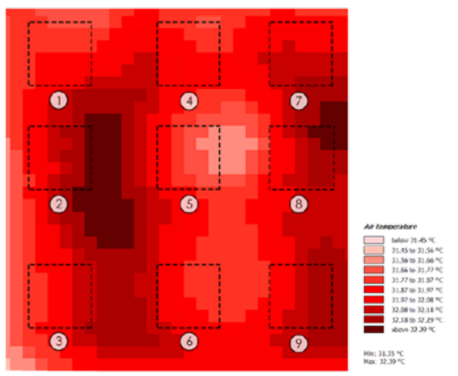


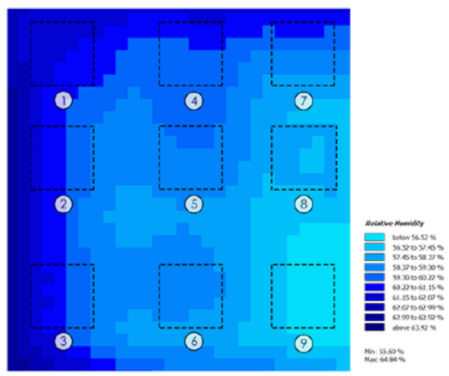



Mean radiant temperature


UTCI


Local wind speed


Air Temperature


Relative Humidity

1. Cylindrical, Medium trunk, Dense, small (5m)
2. Cylindrical, Medium trunk, Sparse, small (5m)
3. Spherical, Medium trunk, Sparse, small (5m)
4. Spherical, Medium trunk, Dense, small (5m)
5. Cylindrical, Medium trunk, Sparse, medium (15m)
6. Spherical, Medium trunk, Sparse, medium (15m)
7. Tree, 20m, Very dense, distinct large crown
8. Hedge (2m)
9. Grass

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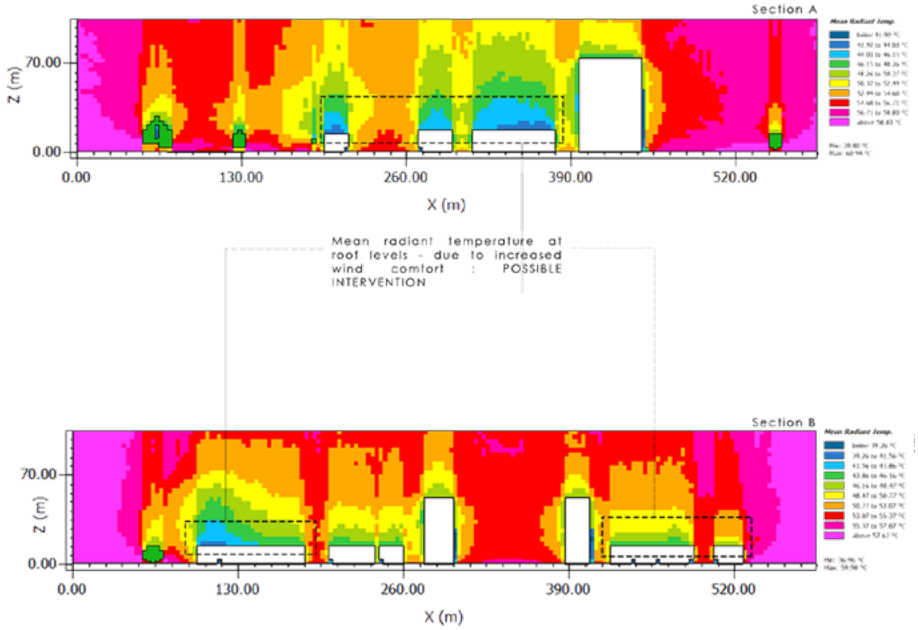
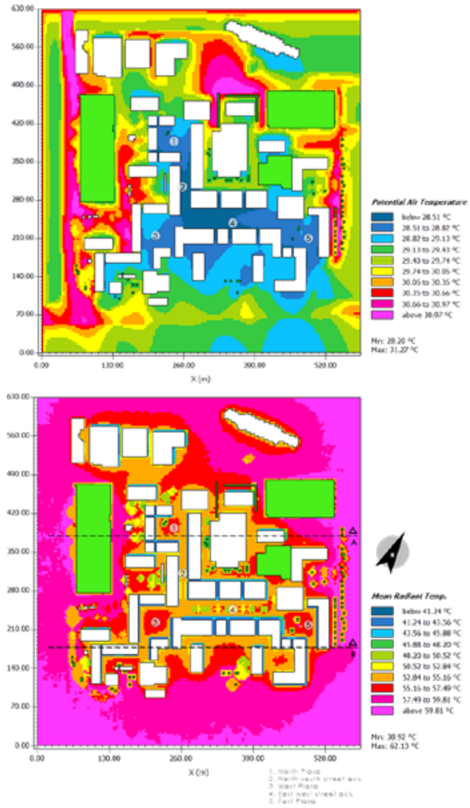
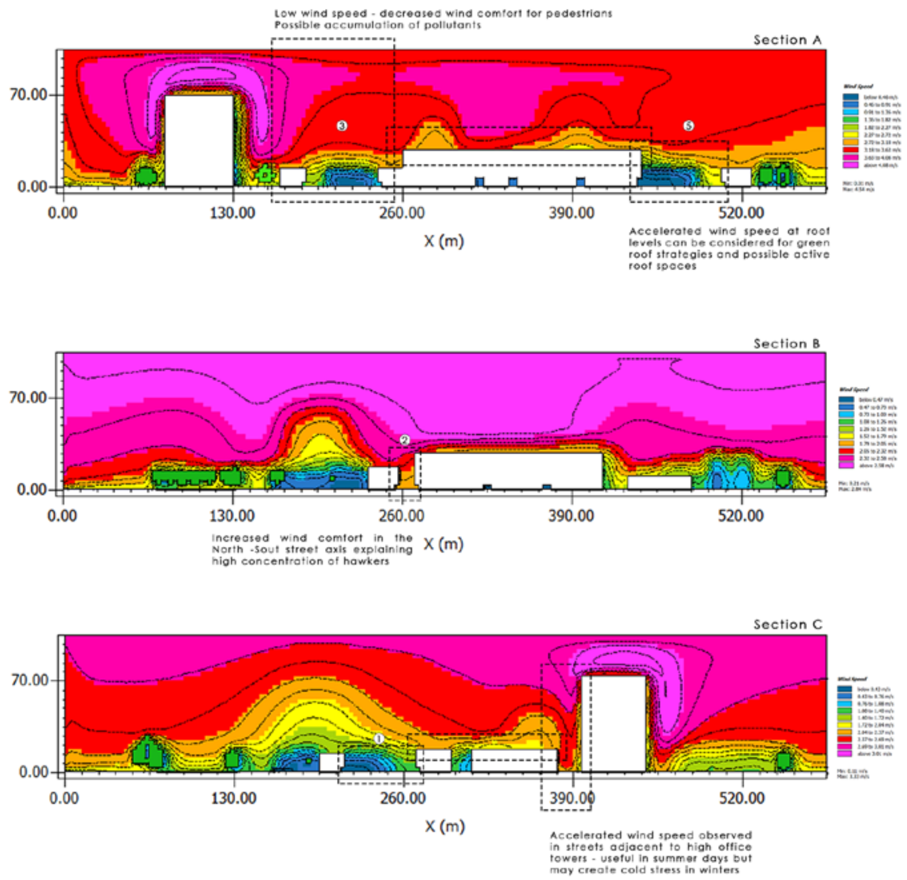
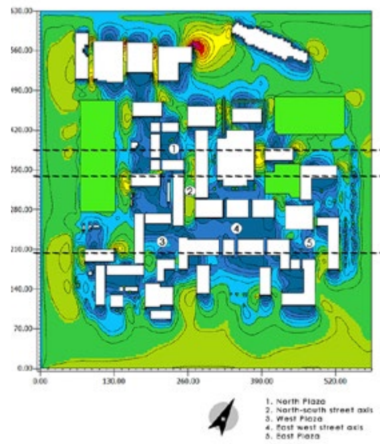
Base scenario - existing air temperatures and wind conditions





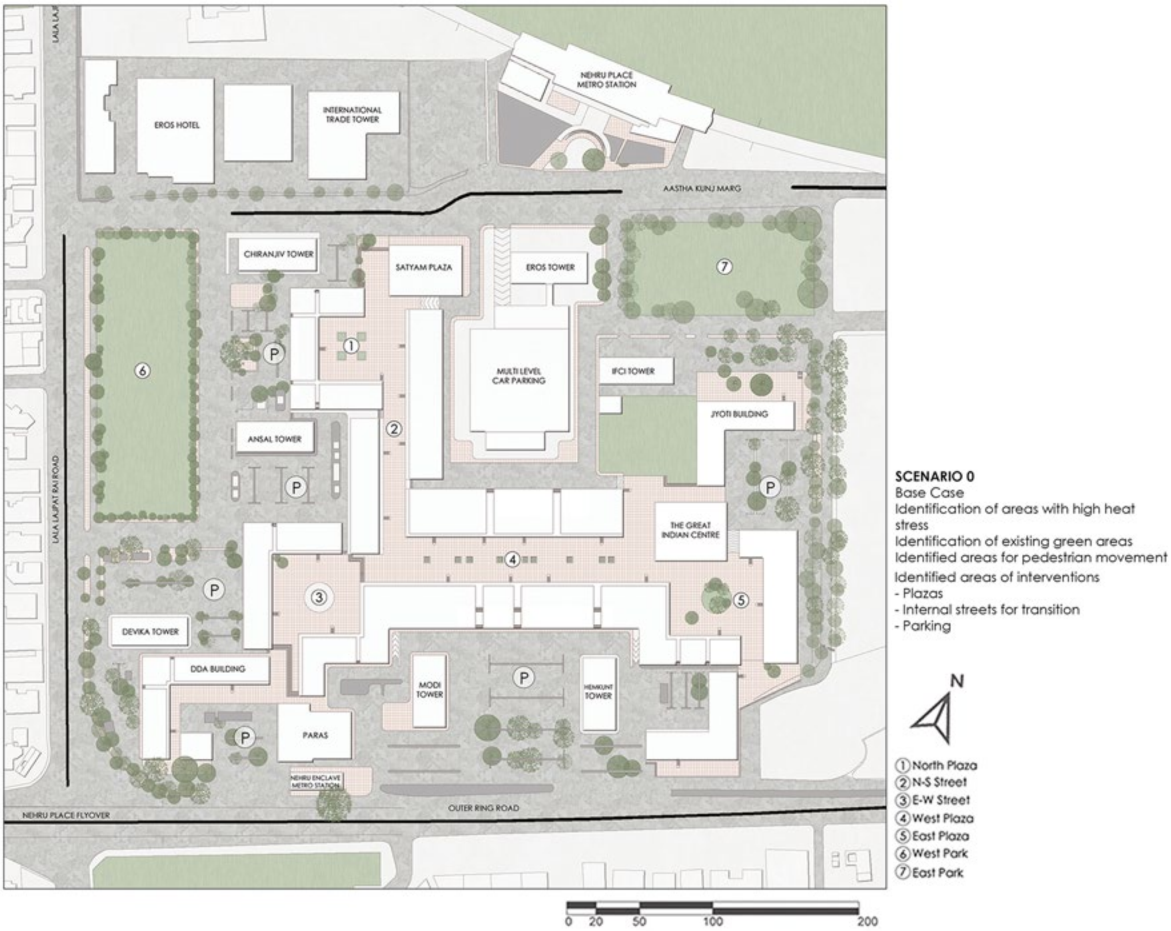




Scenario based analysis for micro climatic studies using ENVI-met

The base site with existing conditions was taken as Scenario 0 maintaining similar characteristics of the existing site.

The first three scenarios were individual scenarios to understand the implication of each of the intervention on the site. Scenario 1 included nature based urban vegetation in and around the open plazas and streets. Scenario 2 took into account the albedo and thermal properties of the materials. Scenario 3 was simulated with green facades and roofs. Scenario 4-6 took into account the combined effect of the first three simulations without eliminating the existing trees and vegetation on the site. All the scenarios were then compared against Universal Thermal climate Index (UTCI) to measure and indicate thermal comfort, highlighting the areas investigated for thermal stress and suitable guidelines that could be followed. On a UTCI scale, temperatures above 46°C accounts for extreme heat stress, between 38-46°C is very strong heat stress, 32-28°C is strong and from 26-32°C is considered moderate. As per the literature analysis, the ultimate idea is to bring the heat stress down to more comfortable indices on the UTCI scale which are achieved through the above-mentioned scenarios.



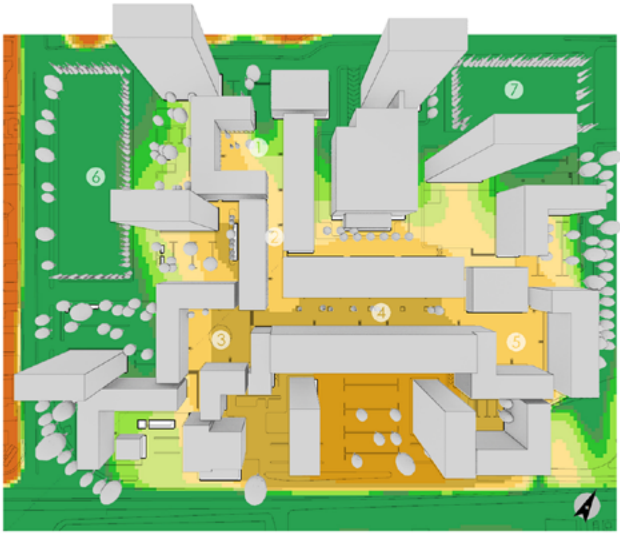
INDIVIDUAL SCENARIOS

SCENARIO 1	SCENARIO 2	SCENARIO 3
Implementing urban greens (street trees, plazas, grass)	Increase in material albedo for plazas, pavements and parking	Green walls and roofs

COMBINED SCENARIOS

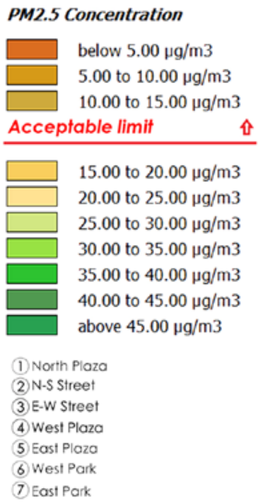
SCENARIO 4	SCENARIO 5	SCENARIO 6
Combining Scenario 1 & 2 Urban greens + Improved material albedo	Combining Scenario 1,2 & 3 Urban greens + facade & roof greens + Improved material albedo	Combining Scenario 1,2 & 3 Urban greens + facade & roof greens + Improved material albedo + Plaza shading

Effects of urban vegetation on plaza levels for scenarios 0, 1 and 3



SCENARIO 0: BASE CASE
PM2.5 concentration at 1.75m above ground level

SCENARIO 1: IMPROVED VEGETATION
PM2.5 concentration at 1.75m above ground level



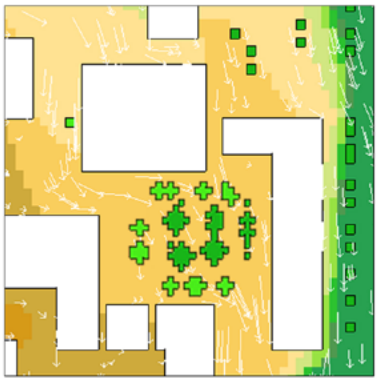
SCENARIO 3: GREEN FACADE AND ROOF
PM2.5 concentration at 1.75m above ground level

1 NORTH PLAZA

- Increase in PM2.5 concentration from 20g/m3 to 30g/m3 in the North Plaza
- Trees concentrating the PM2.5 particles

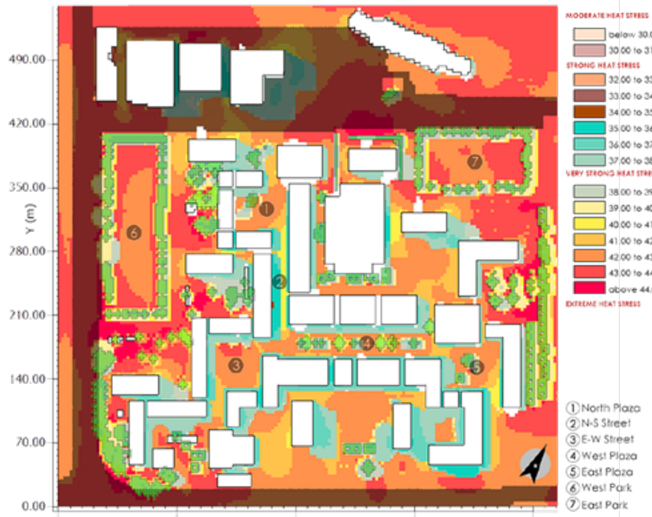
3 WEST PLAZA

-Increase in PM2.5 concentration in West Plaza but within the safe levels (WHO)
- Trees on north accelerate the wind more into the plazas



5 EAST PLAZA

-East plaza shaded by Main wind direction, no change in pollution concentration



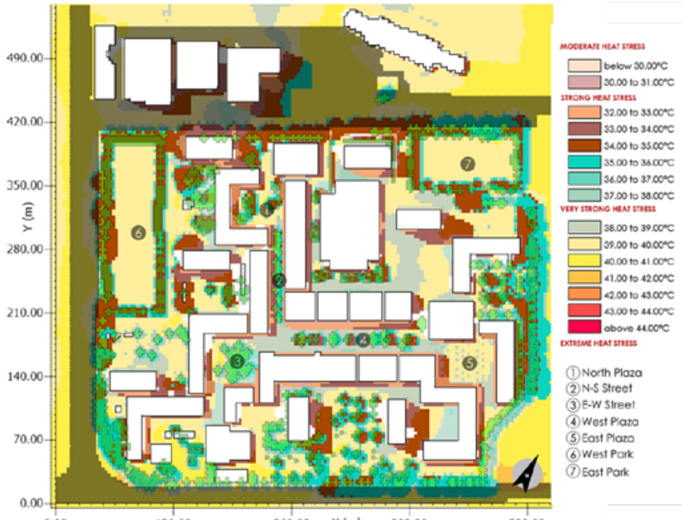
SCENARIO 0: BASE CASE
UTCI at 1.5m above ground level
MIN: 40°C MAX: 50.21°C

SCENARIO 2: Improved Material Albedo
UTCI at 1.5m above ground level
Min: 39.25°C Max:48.95°C

SCENARIO 1: IMPROVED URBAN VEGETATION
UTCI at 1.5m above ground level
MIN: 38.95°C MAX: 49.02°C

SCENARIO 3: Green facade and roofs
UTCI at 1.5m above ground level
Min: 37.90C Max:47.55°C

SCENARIO 4: **COMBINING SCENARIO 1 + 2**
IMPROVED URBAN VEGETATION + MATERIALS
UTCI at 1.5m above ground level
MIN: 37.98°C MAX: 47.55°C



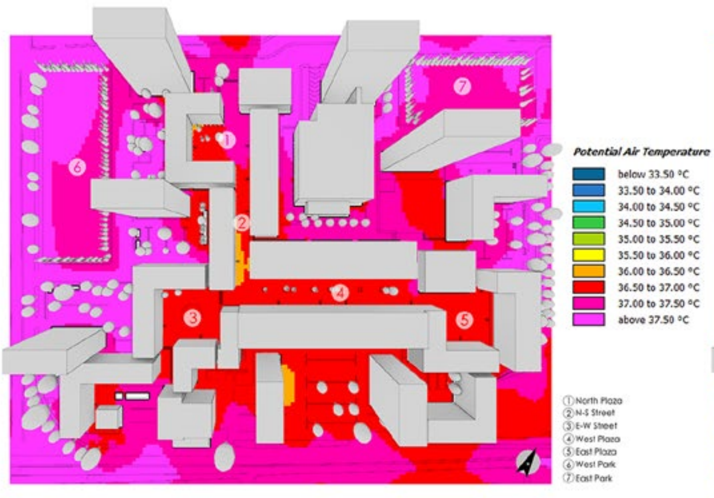
SCENARIO 5: **COMBINING SCENARIO 1 + 2 + 3**
IMPROVED URBAN VEGETATION + MATERIALS + GREEN FACADES & ROOF
UTCI at 1.5m above ground level
MIN: 36.58°C MAX: 46.43°C

Main outcomes - combined analysis Scenario 4, 5 and 6

The first three scenarios were further combined in three different ways:

Scenario 4 highlighted the combined effect of vegetation and materials, Scenario 5 looked at combined effect of urban vegetation, green roofs and walls with materiality and Scenario 6 looked at the effects of shading the urban plazas as an addition to the three interventions.

The simulations compared against the base case scenario showed drastic improvements with average temperatures dropping by 3-4°C from 45.21°C to 41.65°C. Overall in respect to the site Scenario 5 worked best in improving the outdoor thermal comfort in the plazas, internal streets and parking spaces.
Addition of shading in the plazas, however, showed an increase in UTCI temperatures compared to non-shaded spaces, while the shading on the east-west street proved beneficial will temperatures dropping by 2°C. This was really helpful for understanding the hawker location on the site. Moreover, the wind provided additional local comfort as shown. Overall, the vegetation and materiality combined showed a positive improvement in temperature and thermal conditions on the site.



SCENARIO 0: BASE CASE
Potential air temperature at 1.75m above ground level

SCENARIO 5: BEST CASE
Potential Air Temperature at 1.75m above ground level

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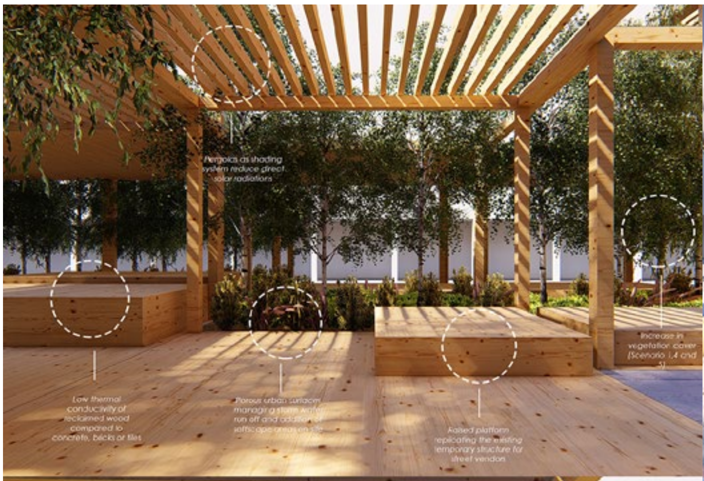
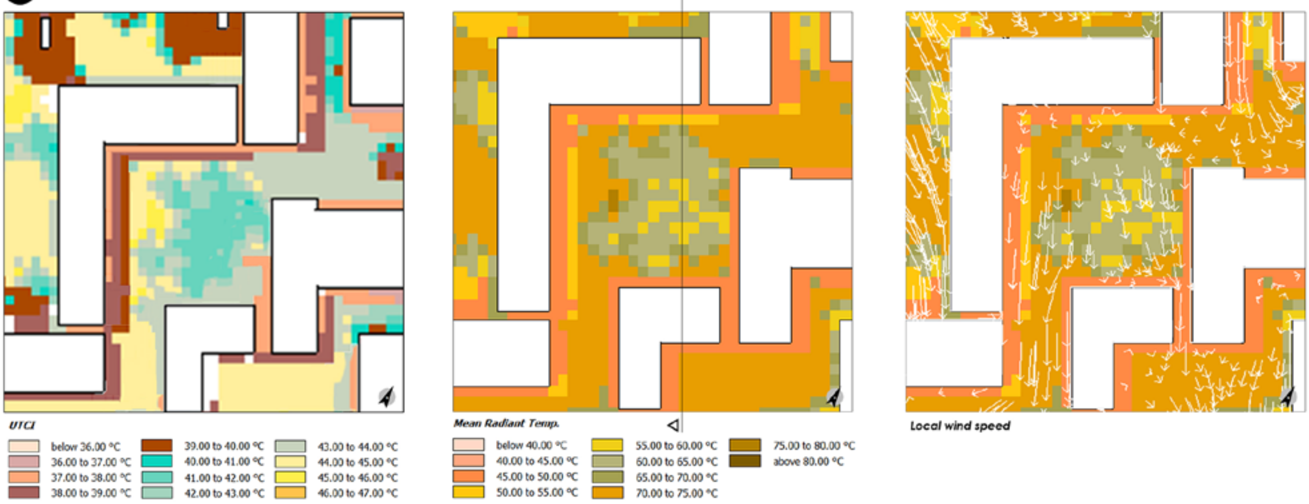
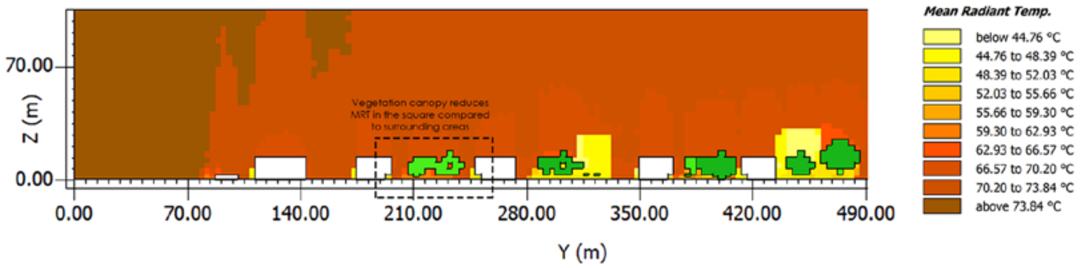

Pergolas as shading system reduce direct solar radiations
Low thermal conductivity of reclaimed wood compared to concrete, bricks or tiles
Raised platform replicating the existing temporary structure for street vendors
Increase in vegetation cover


Brushed Alluminium (high albedo) as a shading element and social interaction space
Utilised for urban furnitures

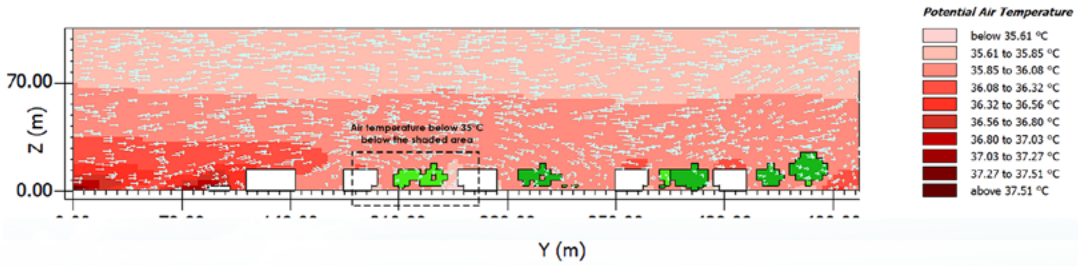
3 West Plaza



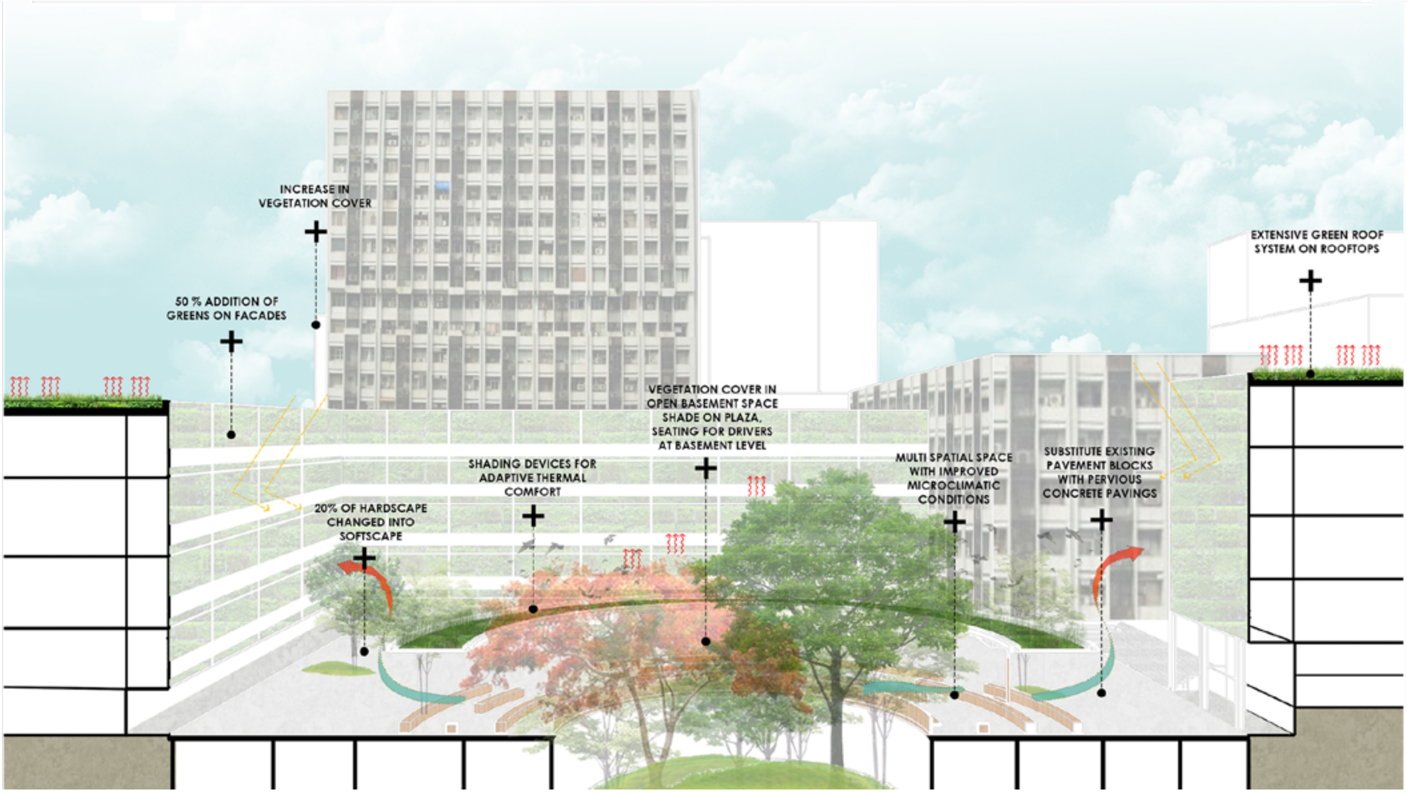
UTCI
below 36.00 °C
36.00 to 37.00 °C
37.00 to 38.00 °C
38.00 to 39.00 °C
39.00 to 40.00 °C
40.00 to 41.00 °C
41.00 to 42.00 °C
42.00 to 43.00 °C
43.00 to 44.00 °C
44.00 to 45.00 °C
45.00 to 46.00 °C
46.00 to 47.00 °C
Mean Radiant Temp.
below 40.00 °C
40.00 to 45.00 °C
45.00 to 50.00 °C
50.00 to 55.00 °C
55.00 to 60.00 °C
60.00 to 65.00 °C
65.00 to 70.00 °C
70.00 to 75.00 °C
75.00 to 80.00 °C
above 80.00 °C
Local wind speed



70.00
0.00
Z (m)
Vegetation canopy reduces MRT in the square compared to surrounding areas
0.00
70.00
140.00
210.00
280.00
350.00
420.00
490.00
Y (m)
Mean Radiant Temp.
below 44.76 °C
44.76 to 48.39 °C
48.39 to 52.03 °C
52.03 to 55.66 °C
55.66 to 59.30 °C
59.30 to 62.93 °C
62.93 to 66.57 °C
66.57 to 70.20 °C
70.20 to 73.84 °C
above 73.84 °C



70.00
0.00
Z (m)
Air temperature below 35°C below the shaded area
Y (m)
Potential Air Temperature
below 35.61 °C
35.61 to 35.85 °C
35.85 to 36.08 °C
36.08 to 36.32 °C
36.32 to 36.56 °C
36.56 to 36.80 °C
36.80 to 37.03 °C
37.03 to 37.27 °C
37.27 to 37.51 °C
above 37.51 °C



INCREASE IN VEGETATION COVER
50 % ADDITION OF GREENS ON FACADES
EXTENSIVE GREEN ROOF SYSTEM ON ROOFTOPS
VEGETATION COVER IN OPEN BASEMENT SPACE SHADE ON PLAZA, SEATING FOR DRIVERS AT BASEMENT LEVEL
SHADING DEVICES FOR ADAPTIVE THERMAL COMFORT
20% OF HARDSCAPE CHANGED INTO SOFTSCAPE
MULTI SPATIAL SPACE WITH IMPROVED MICROCLIMATIC CONDITIONS
SUBSTITUTE EXISTING PAVEMENT BLOCKS WITH PERVIOUS CONCRETE PAVINGS