Impact of URBAN MORPHOLOGY on Microclimatic Conditions and Outdoor Thermal Comfort – A study in mixed residential neighbourhood of Chennai, India

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INTRODUCTION

Urban Areas

Expand boundaries

Altering Urban morphology

URBAN MORPHOLOGY

Density of Buildings

Buildings and its geometry

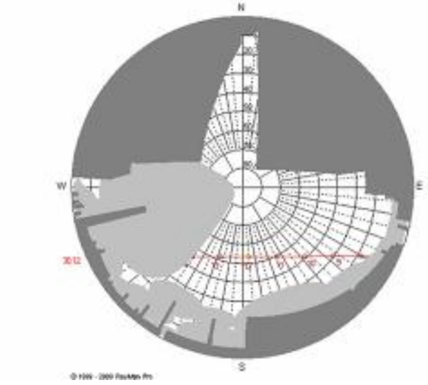
Impervious parking lots

Vegetation

Ground Cover

Ability of the materials to absorb solar radiation (albedo)

Geometrical arrangement of the buildings



Sky View Factor

AIM

The aim of the present study is **to investigate the influence of built geometry and its morphology on the outdoor thermal environment in a mixed residential neighbourhood in the hot humid city of Chennai.**

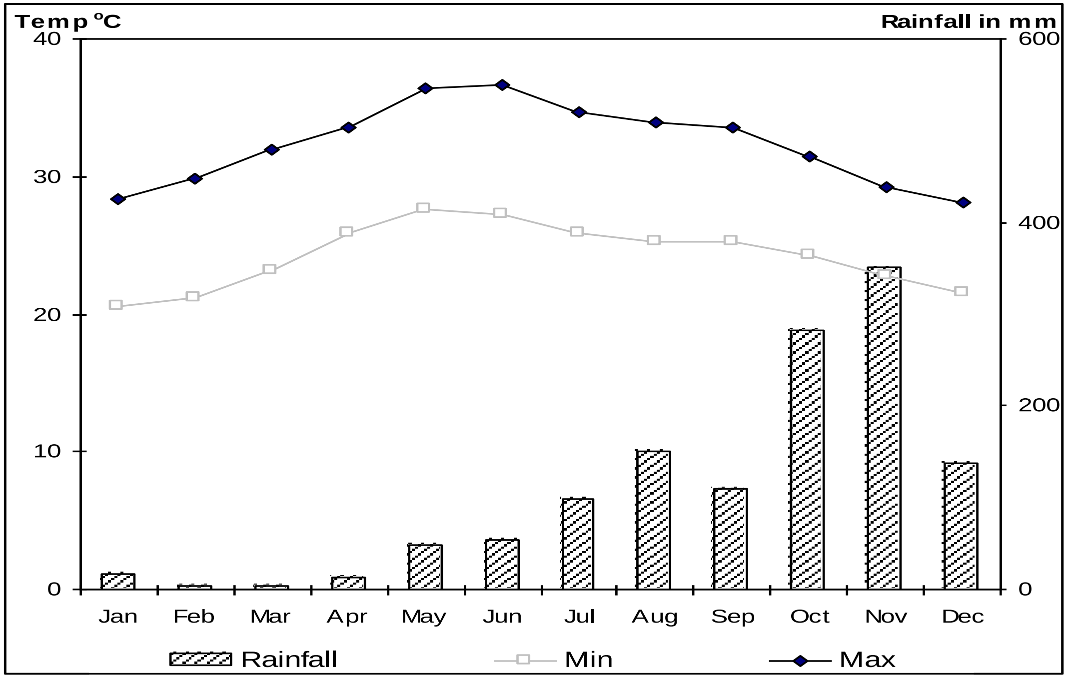
AREA OF STUDY

Location of neighbourhood in Chennai Metropolis and the nine measurement locations.

CHARACTERISTICS OF NEIGHBOURHOOD

- Thiyagaraya Nagar, a **mixed residential neighbourhood**, once planned as a residential neighbourhood, with an **8 acre central park** (Panagal park); has now developed into one of the **busiest shopping districts of Chennai** with shopping activities aligned along all its major arterial roads.
- **Floating population during weekends** reaches to about **5,00,000 people** with majority of them being pedestrians traversing in and around the central park.
- Neighbourhood also houses **two other smaller parks** with one neighbourhood **playground**.
- **Nine measurement locations** were selected in the neighbourhood based on the urban parameters such as amount of vegetation, percentage of urban built-up in terms of buildings, roads and pavements, and canyon geometry (H/W ratio).

CLIMATE OF CHENNAI

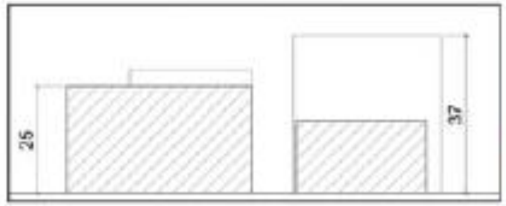
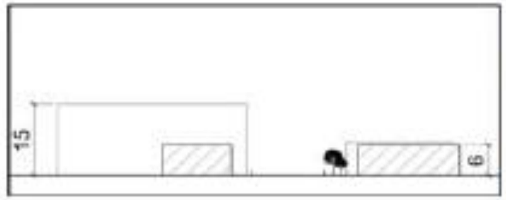
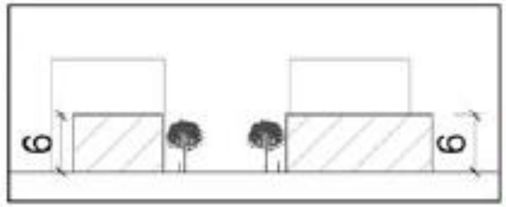
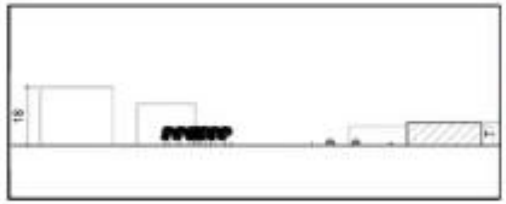
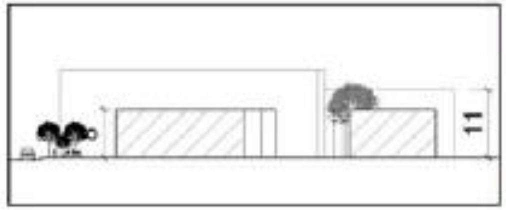


- Mean night time and daytime **temperatures**
  during **Summer** - 28°C and 37°C
  during **Winter** - 20°C and 28°C
  Low diurnal variations < 10°C
- **Relative humidity** - 63% to 80%
- **Vapour pressure** varies between 22hpa and 32hpa.

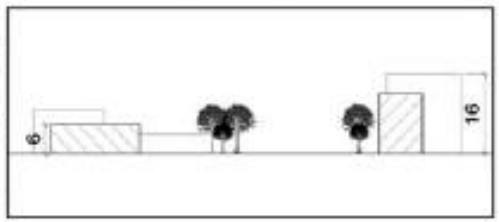
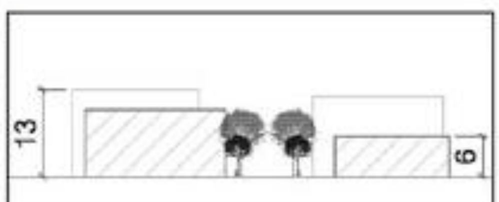
METHODOLOGY

- **Air temperature and Relative humidity** – were measured continuously every half an hour - HOBO dataloggers (HOBO U20 Temp/RH) for a typical winter day (31st January 2013) **at nine locations in the neighbourhoods with different street geometry.**
- **Wind speed** was measured using a hand held Anemometer and **cloud cover data** from Nungambakkam Met. Station.
- MRT were calculated using RayMan Pro with the above **four environmental parameters and two personal** parameters (90W and 0.9 clo)
- **Outdoor thermal comfort conditions** - Physiologically Equivalent Temperature - RayMan Pro model .
- **Questionnaire survey** was also conducted to study the subjective response of pedestrians with respect to outdoor thermal environment.

CHARACTERISTICS OF MEASUREMENT LOCATIONS

		LOCATION	SECTION	VIEW	SVF	H/W
E-W	1				0.220	3.10
E-W	2				0.783	0.70
N-S	3				0.870	0.90
N-S	4				0.636	0.36
N-S	5				0.424	0.95

CHARACTERISTICS OF MEASUREMENT LOCATIONS

		LOCATION	SECTION	VIEW	SVF	H/W
E-W	6				0.567	0.73
NW-SE	7				0.937	0.44
E-W	8				0.770	1.10
E-W	9				0.754	1.05

RESULTS & DISCUSSIONS

- **Influence of urban morphology on outdoor thermal comfort conditions** were analyzed with respect to parameters such as
  - **built-up density**
  - **aspect ratio (H/W ratio) and**
  - **percentage of vegetation / ground cover.**

- **Air temperature, MRT and PET variations were analyzed with respect to the above parameters.**

SKY VIEW FACTOR

DENSITY & ASPECT RATIO

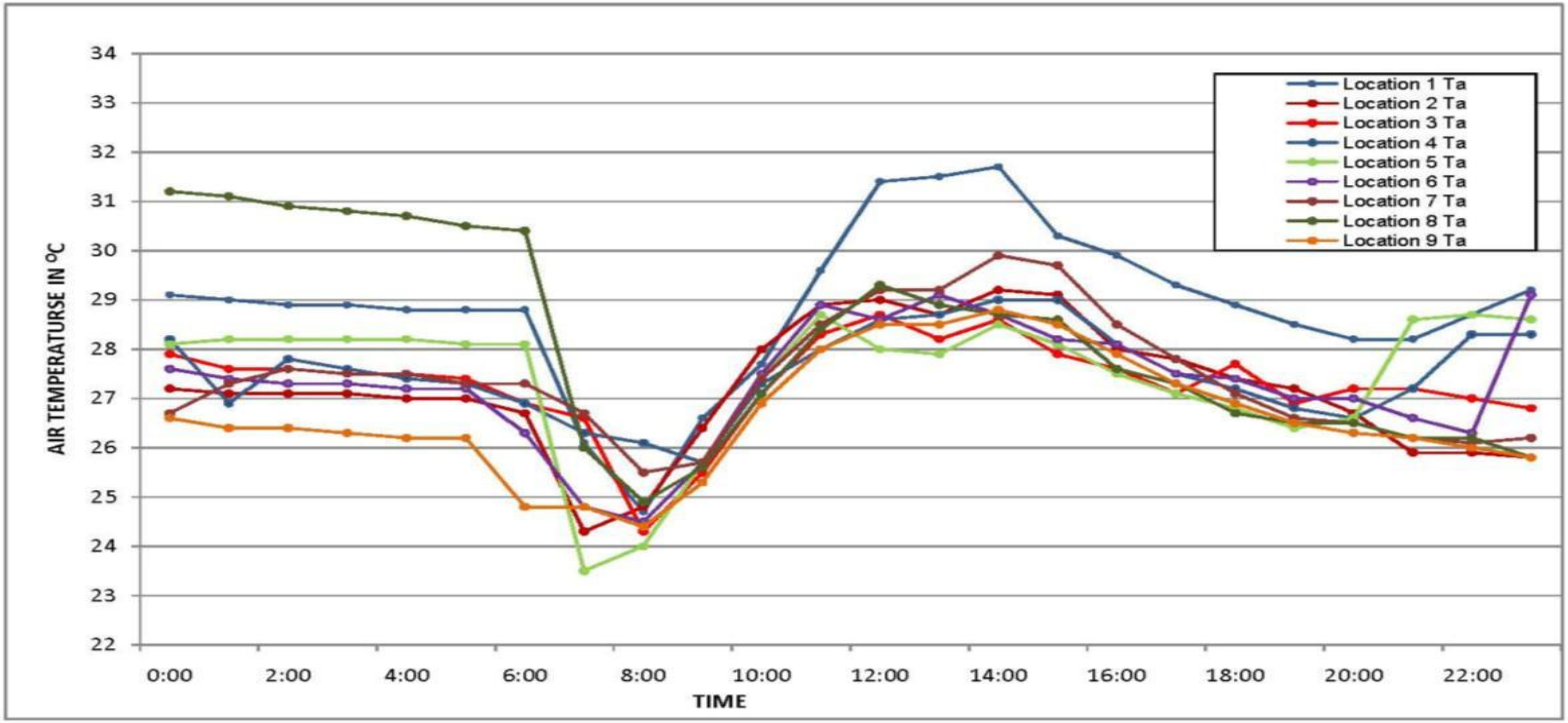
During **nighttime** the Sky view factor (SVF) contributed to the increased air temperatures at the canyon level [illegible] as the heat stored by the building materials during daytime could not be reradiated back to the atmosphere owing to its **lesser SVF.**

Maximum temperatures were recorded at 14:00 hrs in almost all the locations with [illegible]

Location 1 – highest built up density with an aspect ratio of 3.1 [illegible]

Locations 3, 5, 8 & 9 – moderate built up density [illegible] aspect ratios were around 1 [illegible] between the other locations [illegible] respectively

Location 4 – least [illegible] aspect ratio of 0.36 abutting the central park.

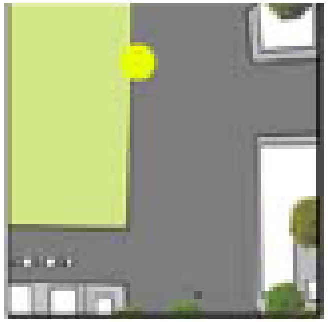


AIR TEMPERATURE VARIATIONS

VEGETATION:

- At locations 3, 4, 7 & 9, **presence of vegetation reduced the daytime air temperatures and** reveals the significance of cooling effect through shading and evapotranspiration.
- At **location 1** the absence of vegetation cover and the **glazed façades** resulted in the **increase of daytime air temperatures.**

Locations 3

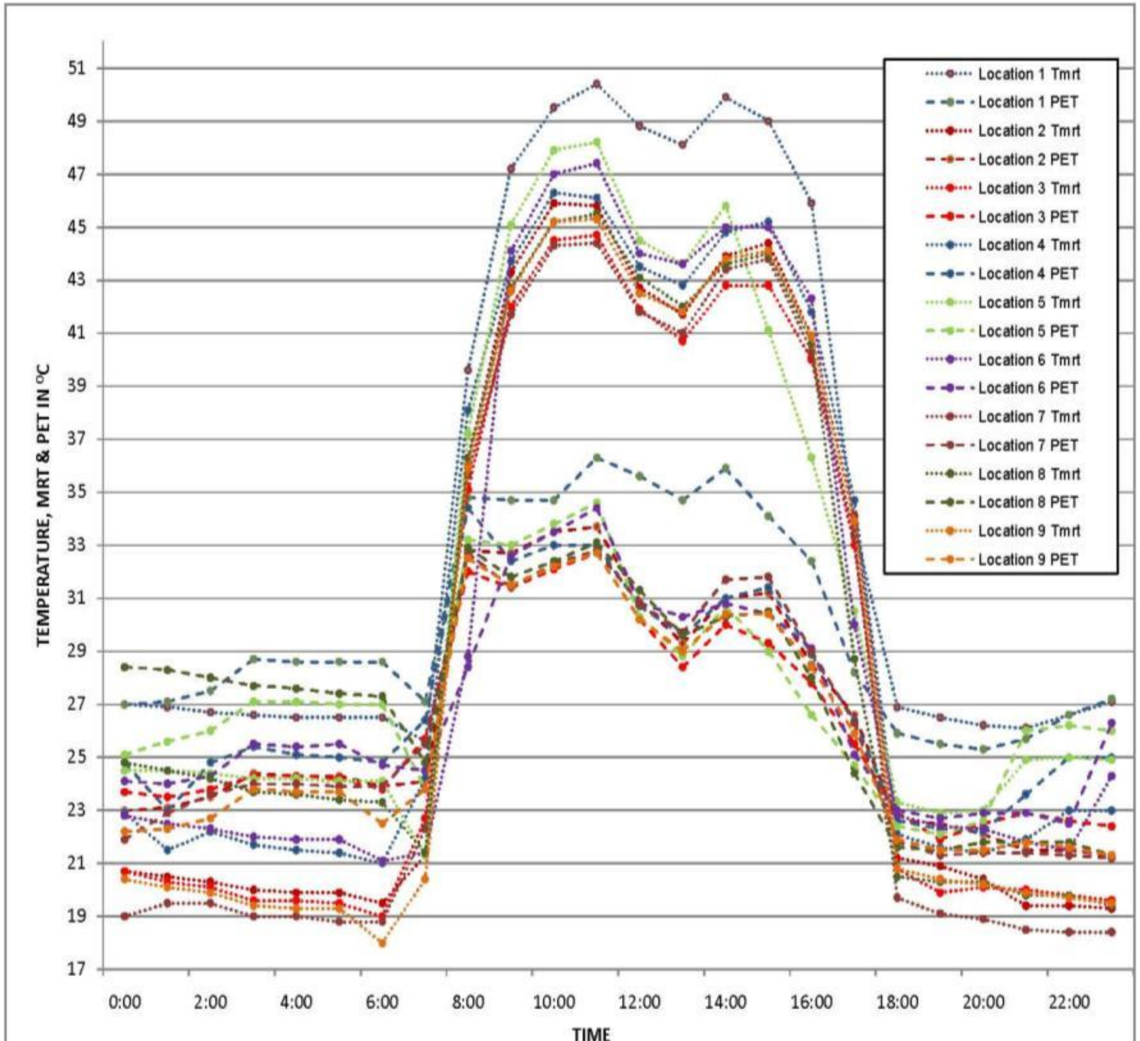


Locations 4

Locations 7

Locations 9

MRT & PET VARIATIONS



SOLAR RADIATION & WIND SPEED

The study revealed a **significant relationship between solar radiation** and **wind speed** on MRT and PET temperatures.

SOLAR RADIATION

Duration of sunshine between 6.00hrs and 18.00hrs **increased the MRT and PET significantly.**

Though the **air temperatures** were within the **comfortable** range, the **intense solar radiation** resulted in **elevating the discomfort in MRT and PET values.**

Maximum MRT and PET temperatures were recorded at **11.00hrs** instead of 14.00hrs.

Higher wind speeds between 12.00hrs and 13.00hrs **reduced the MRT and PET values significantly.**

Location 1

Location 1 experienced the **maximum temperature**, MRT and PET values at 11.00hrs owing to its **E-W orientation** of the street, **H/W ratio of 3.1**, **SVF of 0.220** and **absence of vegetation.**

Also the **congested pedestrian flow**, **absence of shading added to the discomfort.**

Location 3

Location 7

Location 8

Location 9

Locations 3, 7, 8 & 9 recorded **the least MRT and PET** during 11.00hrs **owing to the shading of trees**

Location 4

Location 4 experienced **higher temperatures** even **though abutting the central park.**

This is due to the fact that the location 4 is in the intersection of E_W and N_S street and also **due to the wider aspect ratio of 0.36.**

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Location 2

Location 5

Location 6

Locations 2, 5 & 6 experienced **similar air temperatures**, but the **MRT & PET of Location 2 were higher** than Location 5 & 6. This is due to the fact the **presence of vegetation in location 5 & 6 improved the comfort conditions** when compared to location 2.

QUESTIONNAIRE SURVEY AND COMFORT ANALYSIS

Respondents experienced heat stress during daytime at all locations

- The thermal sensation at **locations 3, 7, 8 & 9 were comfortable due to the shading of trees.**

- **Location 4 abutting the central park was almost tolerable** but was not as comfortable as location 3, 7, 8 & 9, as the park acts as a traffic island and the anthropogenic heat emitted by the vehicles added to the discomfort.

- The thermal sensation of pedestrians at **location 1 was too warm** during daytime as the **heat radiated from the glazed surfaces** of abutting buildings added to the discomfort significantly. Also the **absence of internal shading of buildings** during daytime due to its E-W orientation.

QUESTIONNAIRE SURVEY AND COMFORT ANALYSIS

- The respondents at **locations 2, 5, 6 & 8 complained of heat stress during forenoon when compared to the afternoons**. This is mainly because of the **higher wind speeds experienced in the afternoons increased the comfort levels of the pedestrians.**

- The study revealed that **shading of pedestrians at the street level** especially in **wider street geometries increased the comfort conditions** significantly.

- Also the **pedestrian stretches at location 1 would have been comfortable** if **oriented in the N-S orientation** and the **location of parks should be away from the traffic movement** for better comfort conditions.

CONCLUSION

- **Air temperature, PET & MRT** trends in the neighbourhoods **revealed that the nights were comfortable when compared to day.**
- Daytime comfort was found to have a **significant correlation** with
  - **Built-up density**
  - **street geometry (H/W ratio),**
  - **Orientation**
  - **Sky view factor and**
  - **presence of vegetation**
- Study indicates the **significance of improving the daytime comfort in the neighbourhoods**, **through appropriate built geometry, shading of streets and orientation.**
- The **existence of Urban Heat Island i**n the neighbourhood is **clearly evident during the calm winter night** especially between **4.00hrs and 8.00hrs** and an UHI **intensity of 2.5°C to 4.7°C exists** in the neighbourhood.

CONCLUSION

RECOMMENDATIONS

- **N-S streets are comfortable compared to E-W orientation.** If **E-W orientation is essential in the design,**
  - then **appropriate shading of streets through**
    - **shaded / partially shaded streets are essential**
    - **Projected balconies, and**
    - **Increase in vegetation cover** can improve the pedestrian comfort considerably in neighbourhoods.

Thank you for your attention

Questions……..