Walkability in Urban India

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Image Retrieved from:
- *https://economictimes.indiatimes.com/magazines/panache/things-you-can-do-to-beat-the-heat-this-summer/articleshow/51838086.cms*
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Walkability is a measure of how friendly and welcoming a neighborhood is to pedestrians.

Image Retrieved from: http://smartgrowth.org/create-walkable-neighborhoods/

GOAL

Raise awareness on the importance of well designed urban spaces for better walkability.

Image Retrieved from: https://www.itdp.org/2016/02/17/pune-coimbatore-and-chennai-selected-as-indias-smart-cities/

NEED FOR THE STUDY

Walkability

Health Benefits

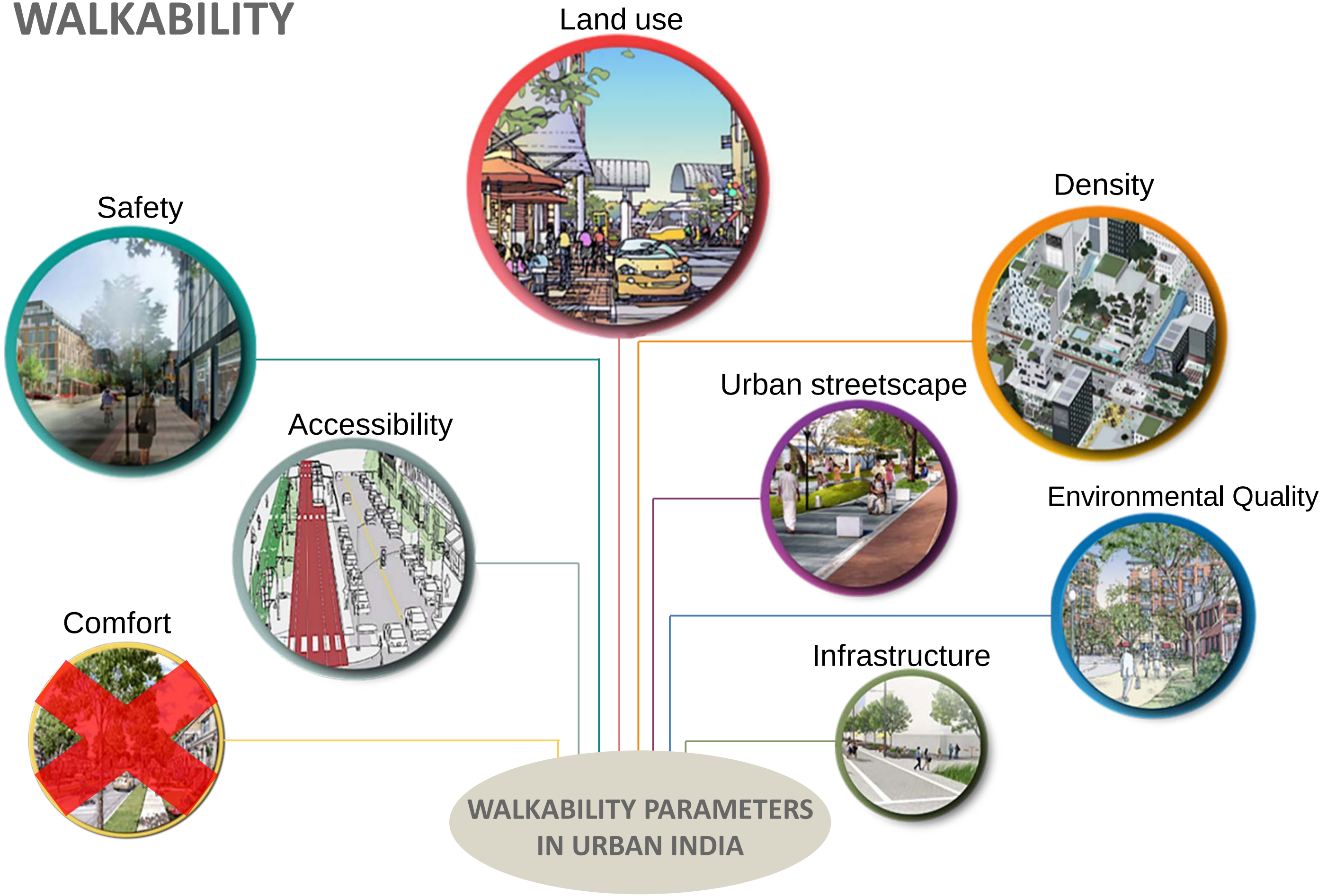
Enhanced `Sense of Place´

Reduced CO_2 emissions

Reclaim the streets

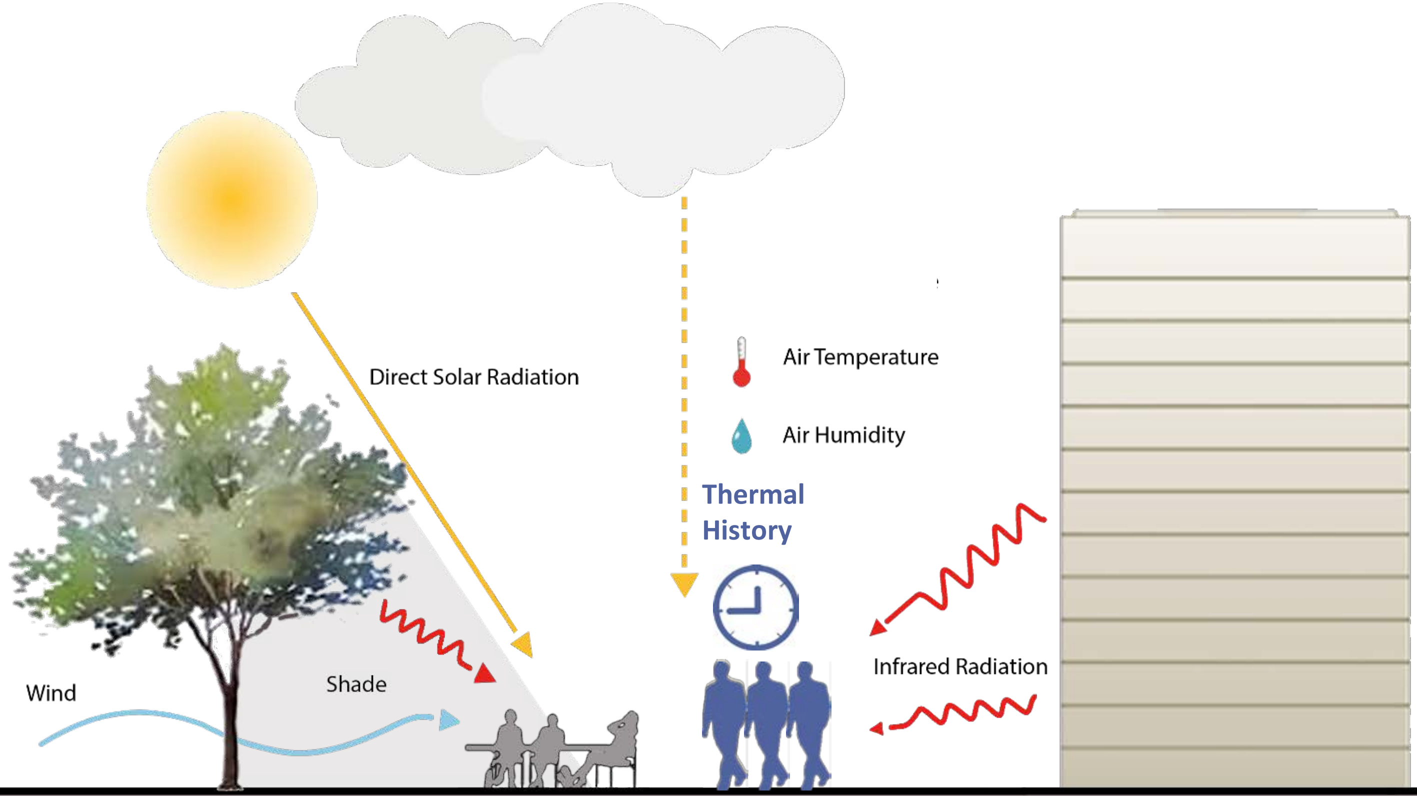
The shift towards active transport contributes to better health, gives residents a Sense of belonging to a place, makes people take possession of streets, and helps improve air quality.

WALKABILITY



Walkabilty in India is influenced by land use, household density, safety, accessibility, aesthetics and urban streetscape, environmental quality, comfort and infrastructure. Pedestrian Thermal comfort is usually not addressed while planning urban neighborhoods in India.

WHAT IS MISSING?



Thermal comfort is usually associated to shade and air temperature. The additional factors are Humidity, infrared radiation, wind, and direct solar radiation.

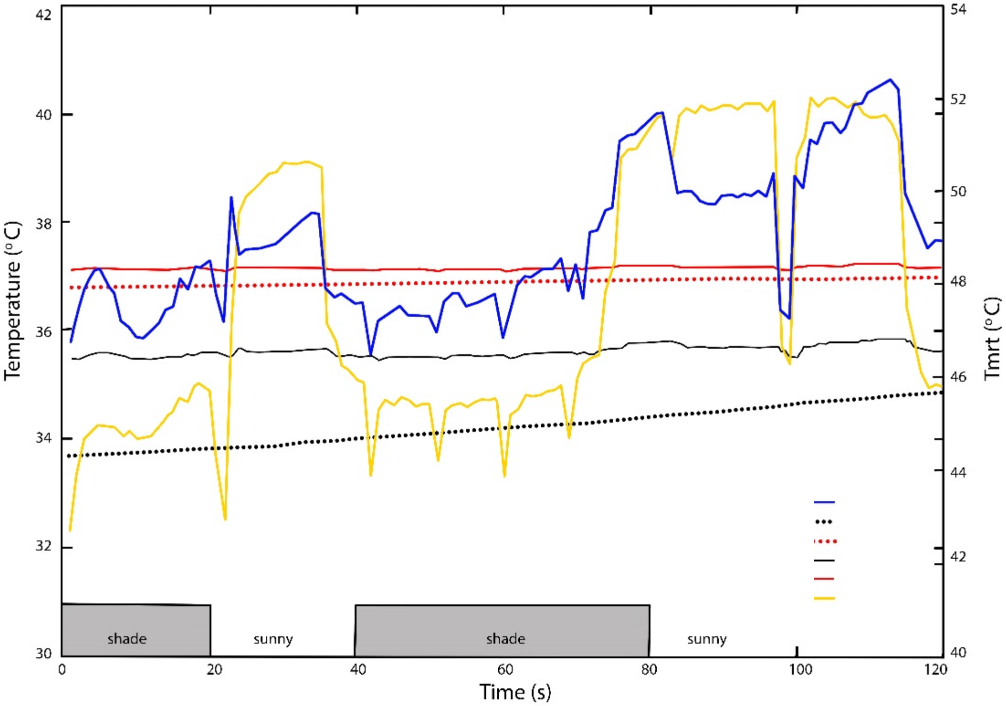
This research takes into account, the influence of time on the thermal comfort of a pedestrian.

Walking comfort: Duration (time) an individual might be able to walk before experiencing discomfort in an outdoor setting.

EXISTING RESEARCH

	PET T mrt	Chosen route
	T skin - st T core - st	Steady State Calculations
	T skin T core	**Transient Calculations**

$T_{skin} \propto$ Time



Temporal variation of a pedestrian

Existing research suggests that the temperature of the skin is transient, it changes with duration of exposure. PET is not time dependent but does change with Mean radiant temperature.

Chen. L, Ng. E, 2011, Assessing pedestrian's thermal transient condition: A bottom-up simulation approach. Retrieved from: The Architectural Science Association, http://anzasca.net/wp-content/uploads/2014/08/49P92.pdf

T_{SKIN} EVALUATION

INTERVIEWS

EQUATIONS

$$T_{cl} = (T_{skin} / I_{cl} + f_{acl} \cdot (h_c \cdot T_a + h_r \cdot T_{mrt})) / (1 / I_{cl} + f_{acl} \cdot (h_c + h_r))$$

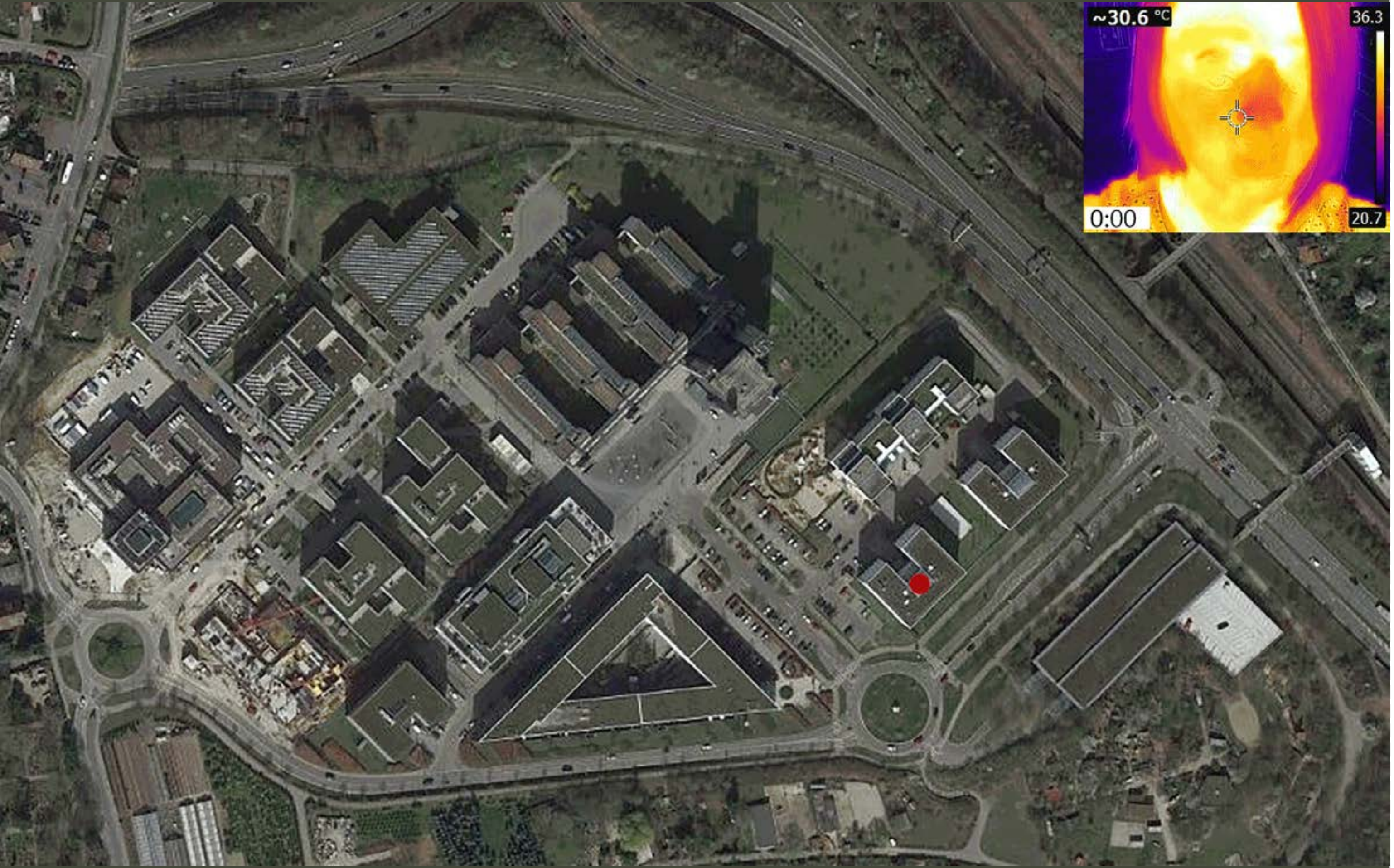
$$S_{core} = M - W - (Q_{c,res} + Q_{e,res}) - Q_{cr->sk}$$

$$S_{skin} = Q_{cr->sk} - (Q_c + Q_r + Q_e)$$

where
T_a is the air temperature;
h_c is the convention heat transfer coefficient;
h_r is the radiant heat transfer coefficient.
In this way, transient T_{skin}, T_{core}, and other thermoregulatory parameters can be calculated by their temporal deviation from the set points.
time interval ranging from 1 sec to 1 min can be selected.
S_{core} is heat storage rate in core;
M is metabolic rate;
W is work;
$Q_{c,res} + Q_{e,res}$ is the total respiratory heat loss (convective and evaporative);
$Q_{cr->sk}$ is the heat flow from core to skin;
$Q_{sk->cr}$ is the heat flow from skin to core;
S_{skin} is the heat storage rate in skin;
$Q_c + Q_r + Q_e$ is the total evaporative heat loss at skin surface (convective, radiative, and sweating).

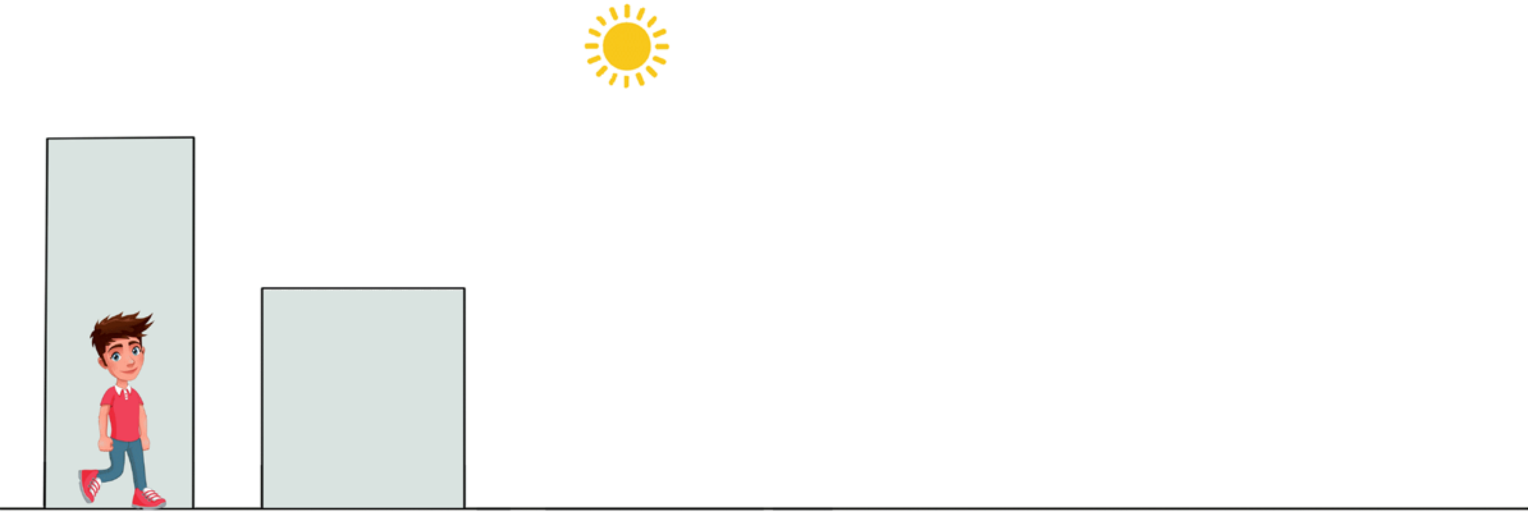
Tskin variation over time can be evaluated by measuring the skin temperature using a thermal camera or by using the equations.
It would be ideal to use the findings to propose efficient neighborhood designs.

Chen. L, Ng. E, 2011 Computer simulation of pedestrian's transient thermal comfort in a complex urban context: a bottom-up modeling approach. Retrievedfrom:http://nceub.org.uk/w2012/pdfs/extra_papers/W1299%20Chen.pdf



The change in skin temperature over time, and in the presence of shade was documented. It is seen that skin temperature increases with constant solar exposure. Also, skin temperature reduces significantly when there a transition from being exposed to the sun to moving to a shaded space.

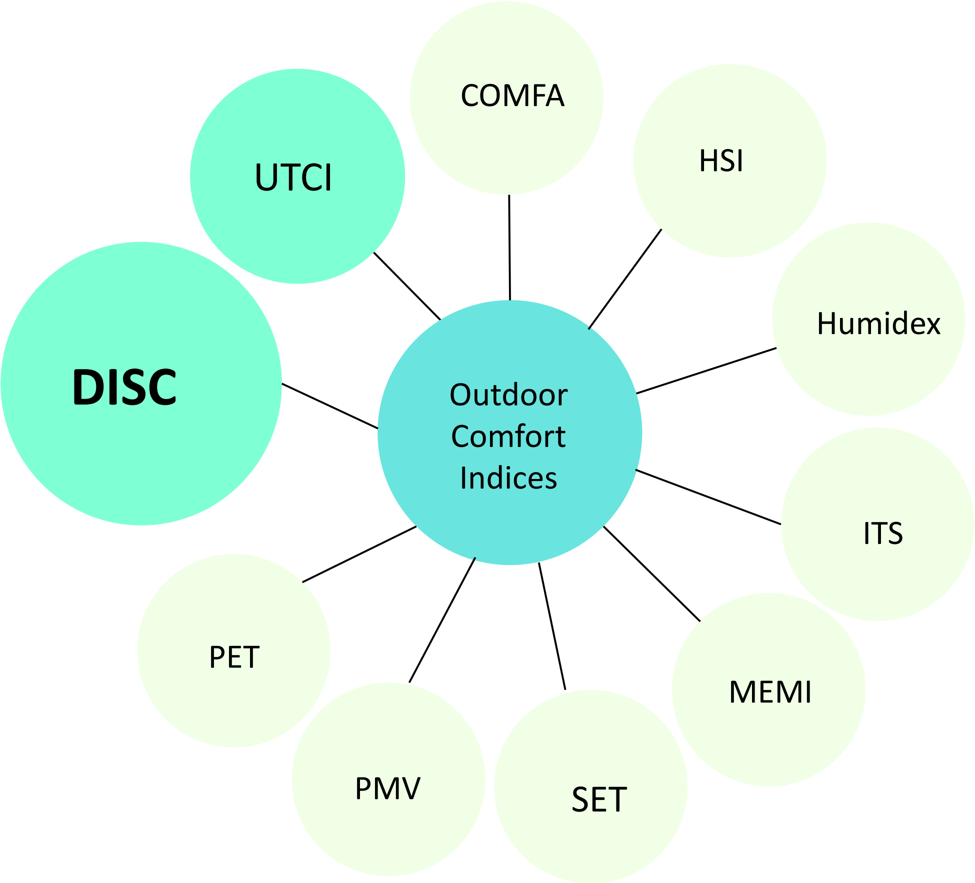
DESIGN HYPOTHESIS



Comfortable Urban Design

When a pedestrian walks in the absence of shade, discomfort sets in. But when there is a transition into a shaded space, the walk becomes more comfortable. When the walk is comfortable, there is a desire to walk longer. With better urban design, pedestrians can be motivated and remain outdoors longer.

INDICES



- **Relative thermoregulatory strain** needed to bring about a state of **thermal equilibrium**
- **Evolves with time**, not steady state

There are several indices that been sued in the past, but for the purpose of this study, DISC is used. Disc is based on the heat balance model of predicting thermal comfort, but the model evolves with time and is not in steady-state.

THERMAL COMFORT INDEX CALCULATOR

INPUTS

Architectural Science
Professor Richard de Dear

The University of Sydney
Australia

Select Input Parameters

Environmental Parameters		Personal Parameters	
ambient temperature (°C)	36.6	subject weight (kg)	70.0
radiant temperature (°C)	23.19	subject surface area (m^2)	1.7
barometric pressure (hPa)	1013	clothing insulation (clo)	0.65
H_2O vapour pressure (hPa)	17.99615	metabolic rate ($W\ m^{-2}$)	70
relative humidity (%)	32	work rate - external ($W\ m^{-2}$)	0
air velocity ($m\ s^{-1}$)	2	exposure time (min)	4

Form of Output

Transient Values

*PS: The result will be displayed in a new window.

Calculate Reset

OUTPUT

Comfort Model STDOUT

Effective Temperature (ET*)	42.39	
Standard Effective Temperature (SET*)	42.56	
Discomfort (DISC)	3.87	Very Uncomfortable!
Thermal Sensation (TSENS)	0.90	Slightly Warm
Predicted Mean Vote (PMV)	5.48	Very Hot!!
Predicted Percentage Dissatisfied (PPD)	100.00	
Heat Stress Index (HSI)	217.41	

DISC scale	
0	comfortable, pleasant
-1, +1	uncomfortable but acceptable
-2, +2	uncomfortable and unpleasant
-3, +3	very uncomfortable
-4, +4	limited tolerance
-5, +5	intolerable

The WWW Thermal Comfort Index Calculator by de Dear: https://web.arch.usyd.edu.au/~rdedear/

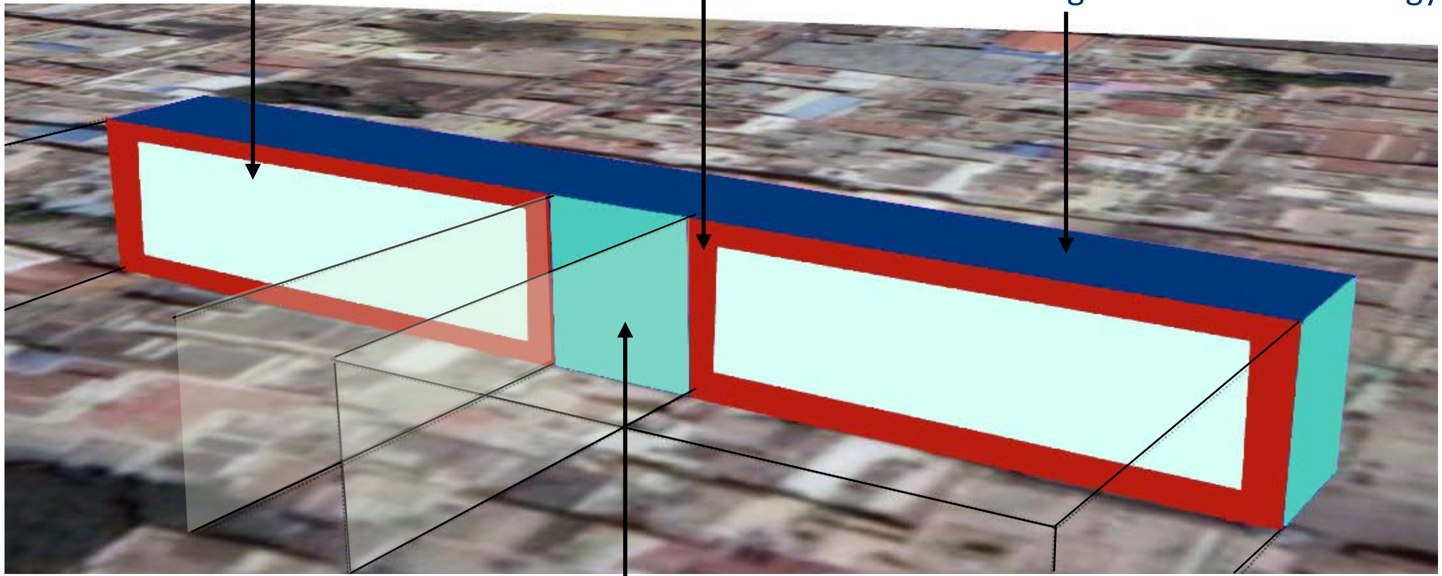
This tool developed by the University of Sydney has DISC as an output. Using inputs such as ambient temperature, radiant temperature, relative humidity, air velocity, clothing factor, and metabolic rate, the discomfort of a pedestrian can be calculated over a period of time.

THERMAL MODEL

Window (Double Glazing)
T*boundary* = Indoor temp.

Ext Wall
T*boundary* = Indoor temp.

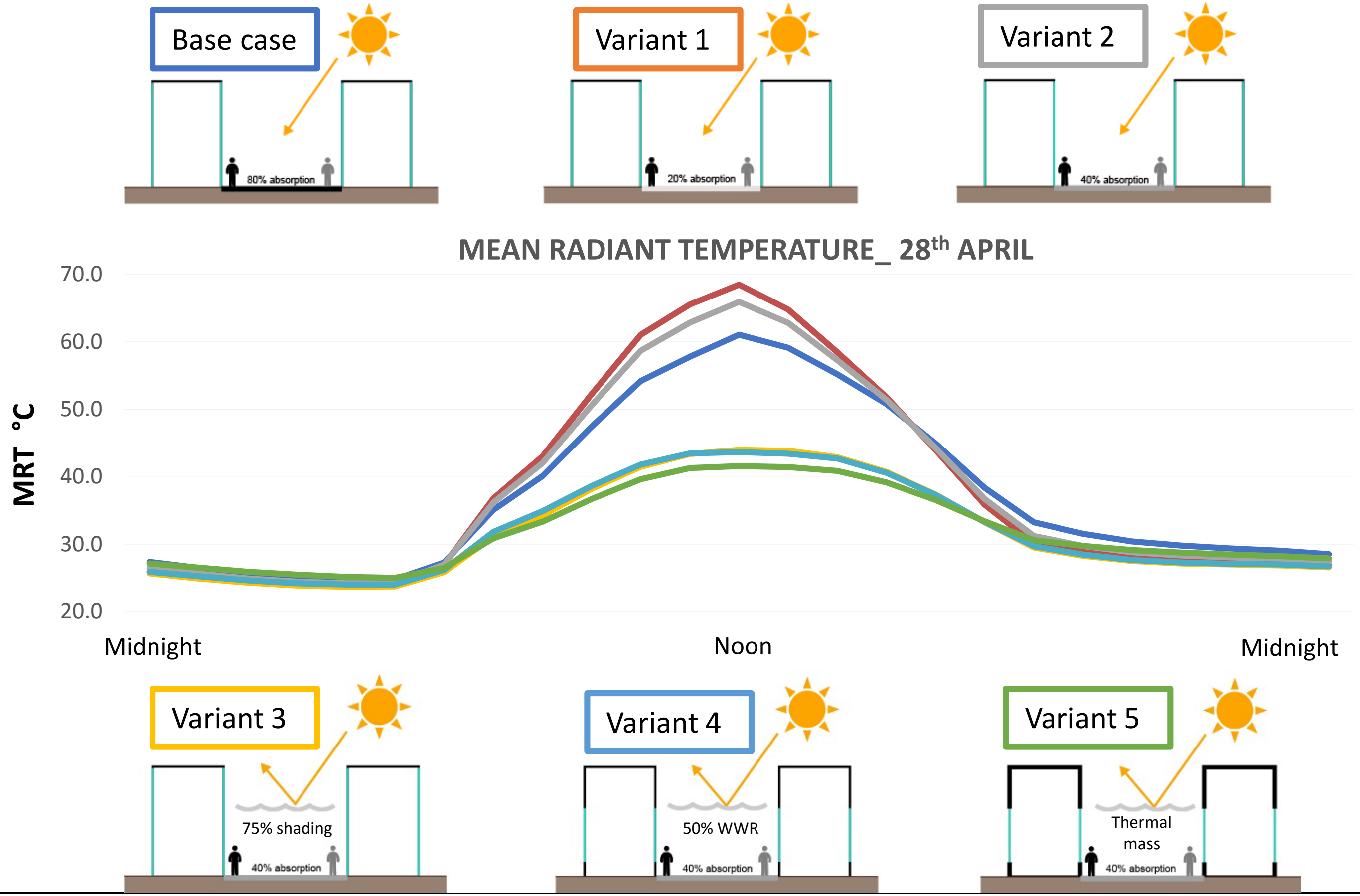
Ceiling (no glass)
T*boundary* = SKY
Inside surface gain = - absorbed energy



Window (No glass)
T*boundary* = Average indoor temperature of inside wall

A street has been modeled, and since this is an outdoor comfort model, the properties are flipped as compared to a regular indoor model. The ceiling (no glass) is assumed to have the temperature same as the sky. The adjacent walls and windows have the indoor temperature of the building.

VARIANTS



Starting with the existing scenario, the Mean radiant temperature is analyzed for different variants on the hottest day in Bangalore.

Variants include

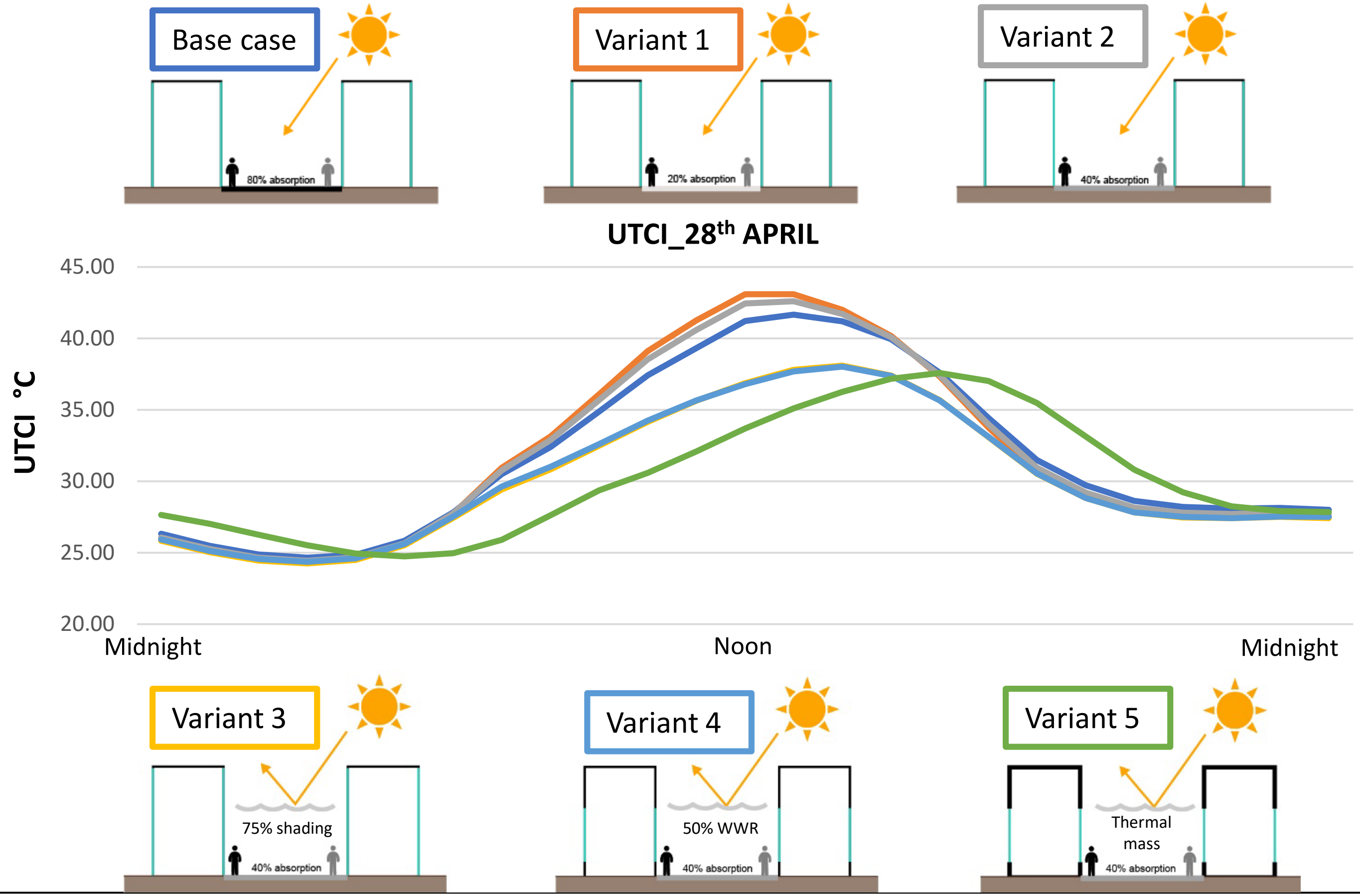
Reflective flooring

75% shading

Lower Window to wall ratio,

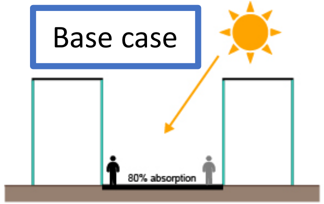
Increase in thermal mass of adjacent walls

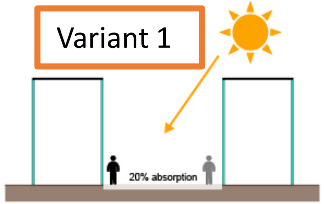
VARIANTS

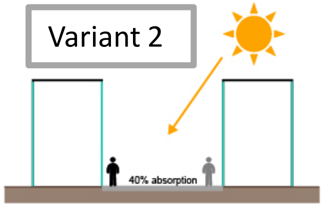


Starting with the existing scenario, the UTCI is analyzed for different variants on the hottest day in Bangalore. The UTCI value reduces from 45° C to 35°C at the hottest hour.

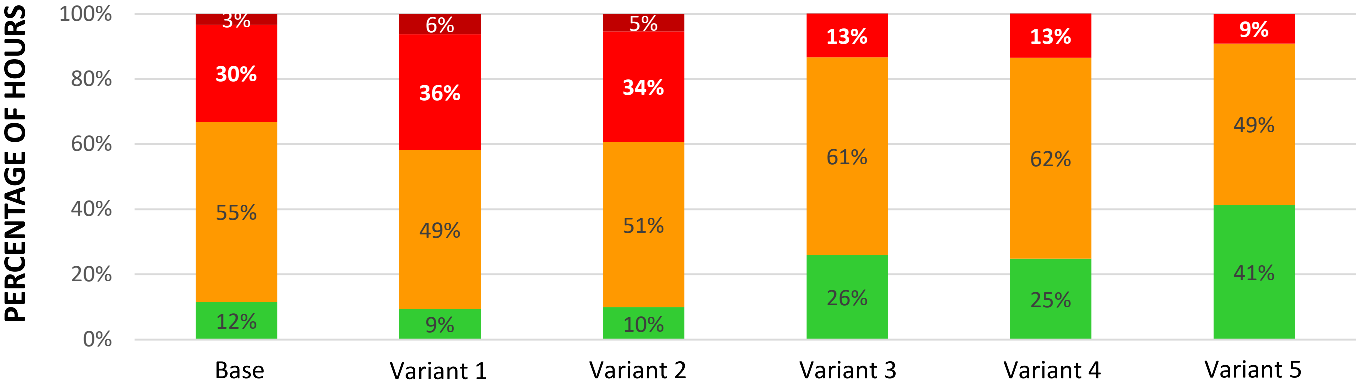
VARIANTS

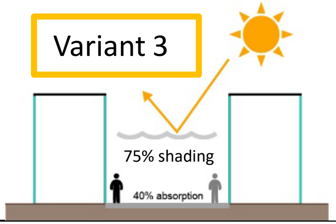


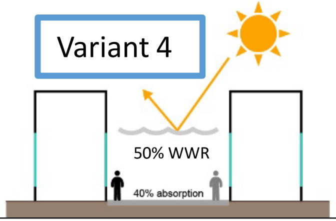


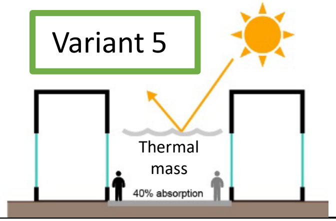


UTCI_ Percentage of sunshine hours

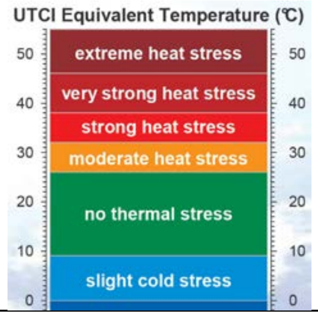


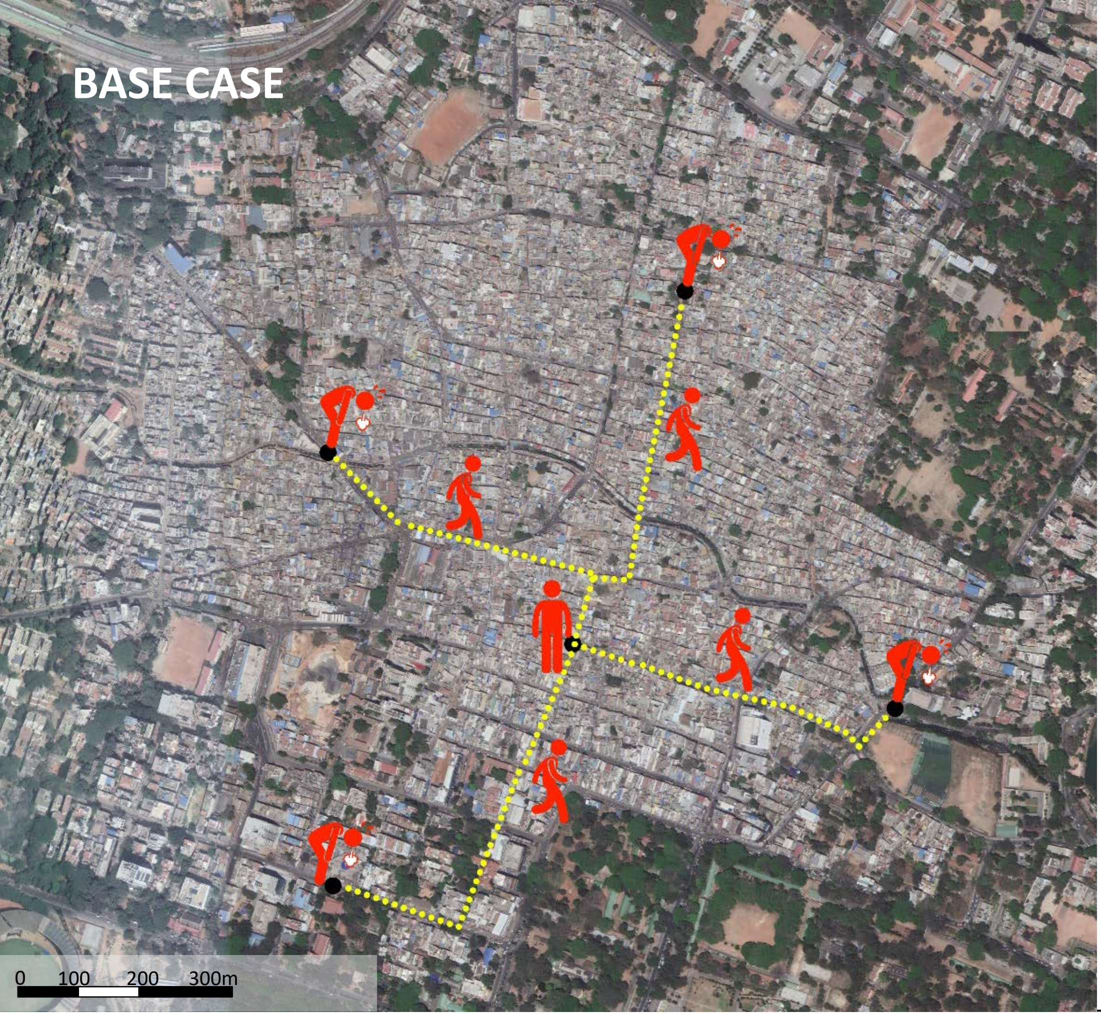






UTCI has been studied for the sunshine hours through the year. By altering the paving material, WWR, providing shading, and thermal mass of adjacent walls the number of hours that are in a comfortable range increase between the base case and variant 5. In the best case, strong heat stress is felt 10% of the time.





28th April, 14:00

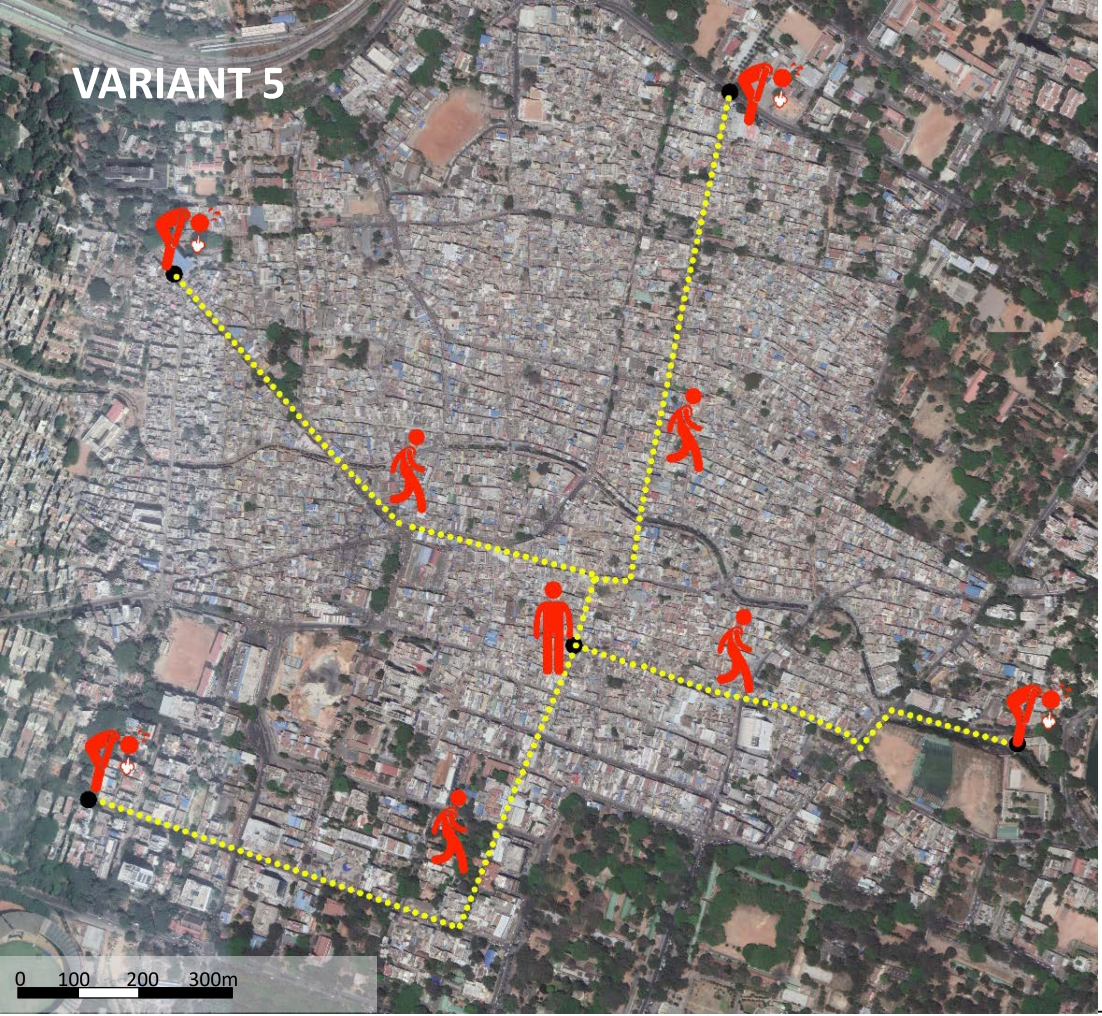
Tair	36.6 °C
RH	32 %
MRT	**61 °C**
Clo	0.65
Walking speed	1.4m/s
Metabolic Rate	150W/m^2

Uncomfortable + unpleasant @ 6mins

Time step	DISC	Distance(m)
1	-0.12	84
2	-0.05	168
3	0.17	252
4	0.98	336
5	1.62	420
6	**2.14**	**504**

The time step at which a pedestrian starts to feel uncomfortable while walking at a speed of 1.4m/s has been analysed. In the existing situation, a pedetsrian can walk 6 minutes before feeling uncomfortable and unplesant.

DISC scale	
0	comfortable, pleasant
-1, +1	uncomfortable but acceptable
-2, +2	uncomfortable and unpleasant
-3, +3	very uncomfortable
-4, +4	limited tolerance
-5, +5	intolerable



28th April, 14:00

Tair	36.6 °C
RH	32 %
MRT	**41.4 °C**
Clo	0.65
Walking speed	1.4m/s
Metabolic Rate	150W/m^2

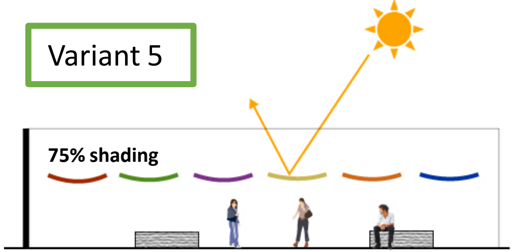
Uncomfortable + unpleasant @ 10mins

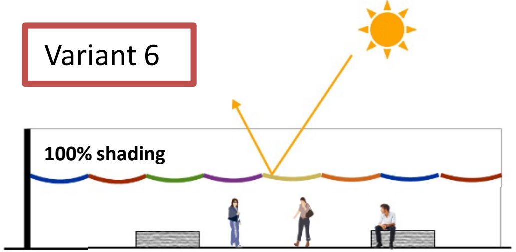
Time step	DISC	Distance (m)
1	-0.12	84
2	-0.07	168
3	-0.03	252
4	0.1	336
5	0.57	420
6	0.96	504
7	1.29	588
8	1.58	672
9	1.84	756
10	**2.07**	**840**

In variant 5, where the paving material, WWR, thermal mass of adjacent walls have been altered and shading elements have been added, the MRT is seen to reduce. As per the time step analysis, here thermal disscomfort sets after walking for 10 minutes with an average velocity of 1.4m/s.

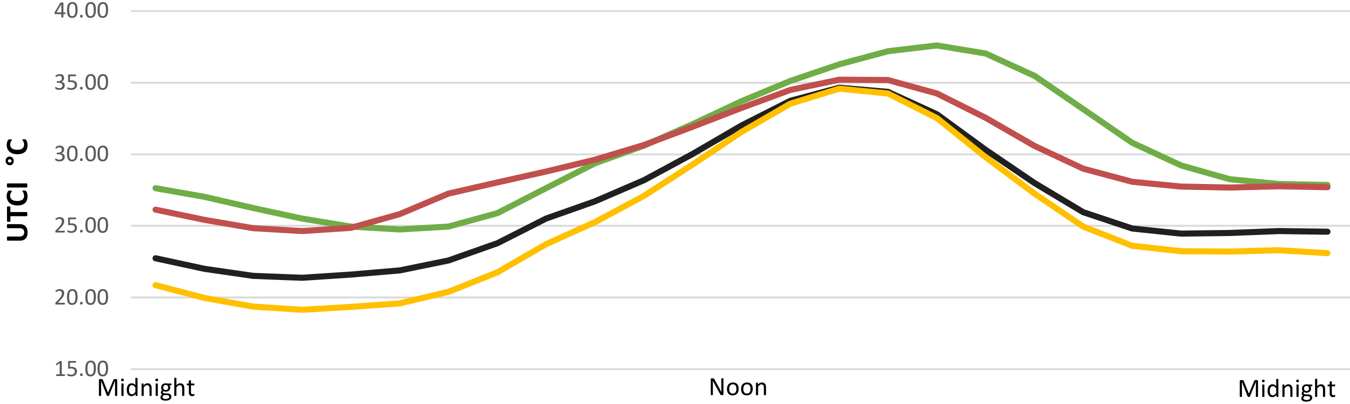
DESIGN INTENTION

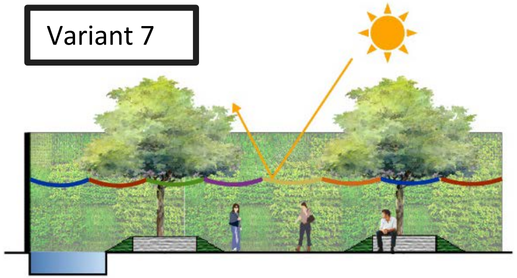
In the best case scenario, discomfort sets in after walking for 10minutes. For several people, a commute can be greater than 850meters or 10minutes. For this purpose, cool spots can be designed at 850 meters or 10minute walking intervals. A pedestrian can stop by at a COOL POCKET, cool down and continue walking.

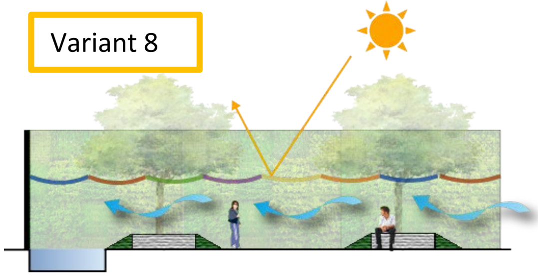




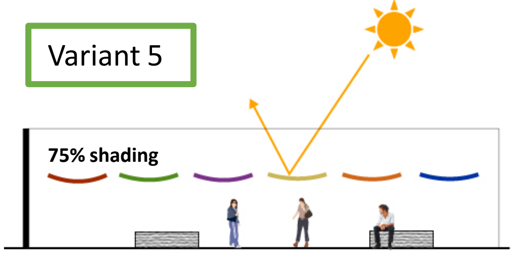
UTCI_28th APRIL

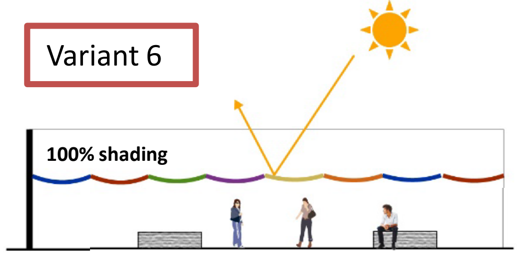


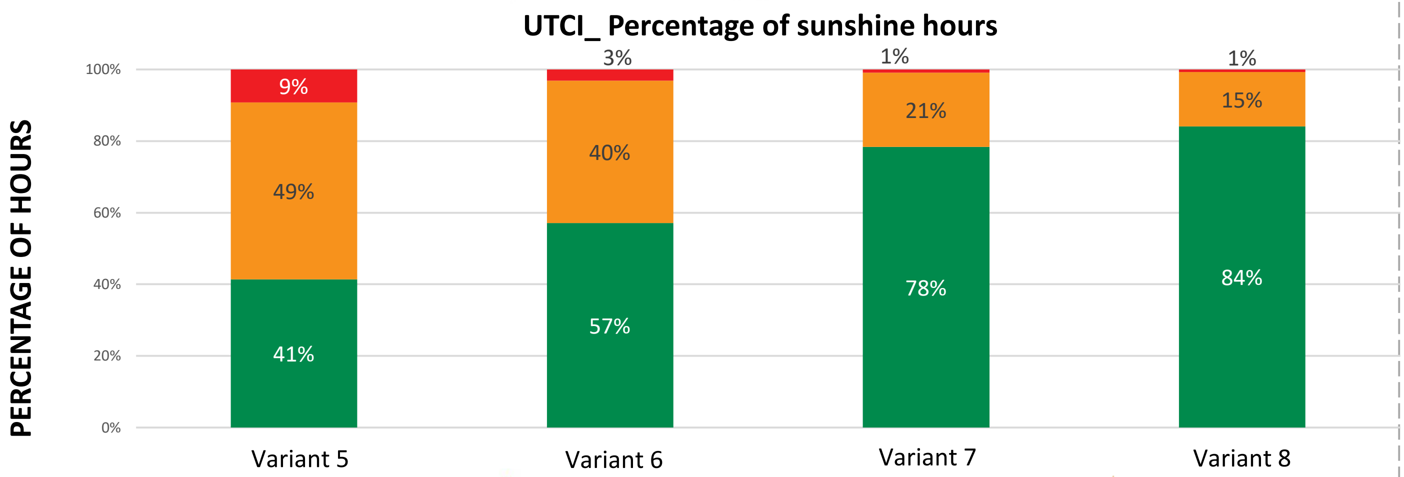


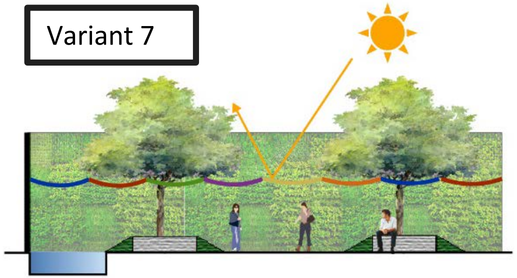


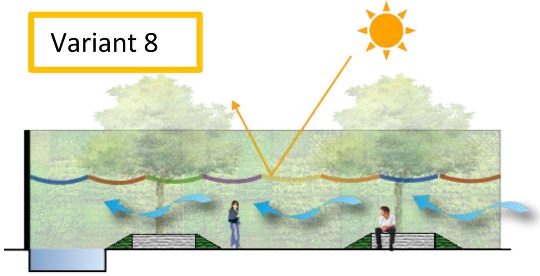
The thermal model of the cool pocket was modelled using the properties of the base variant of the street canyon. The variation of the cool pocket include: 100% shading, addition of evapo-transpiration by having a waterbody and green walls, and elevated wind speed of 2m/s.



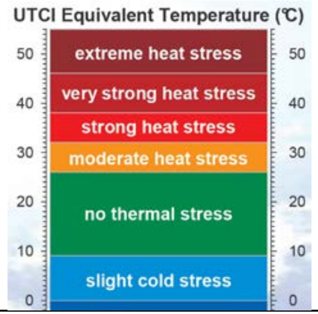




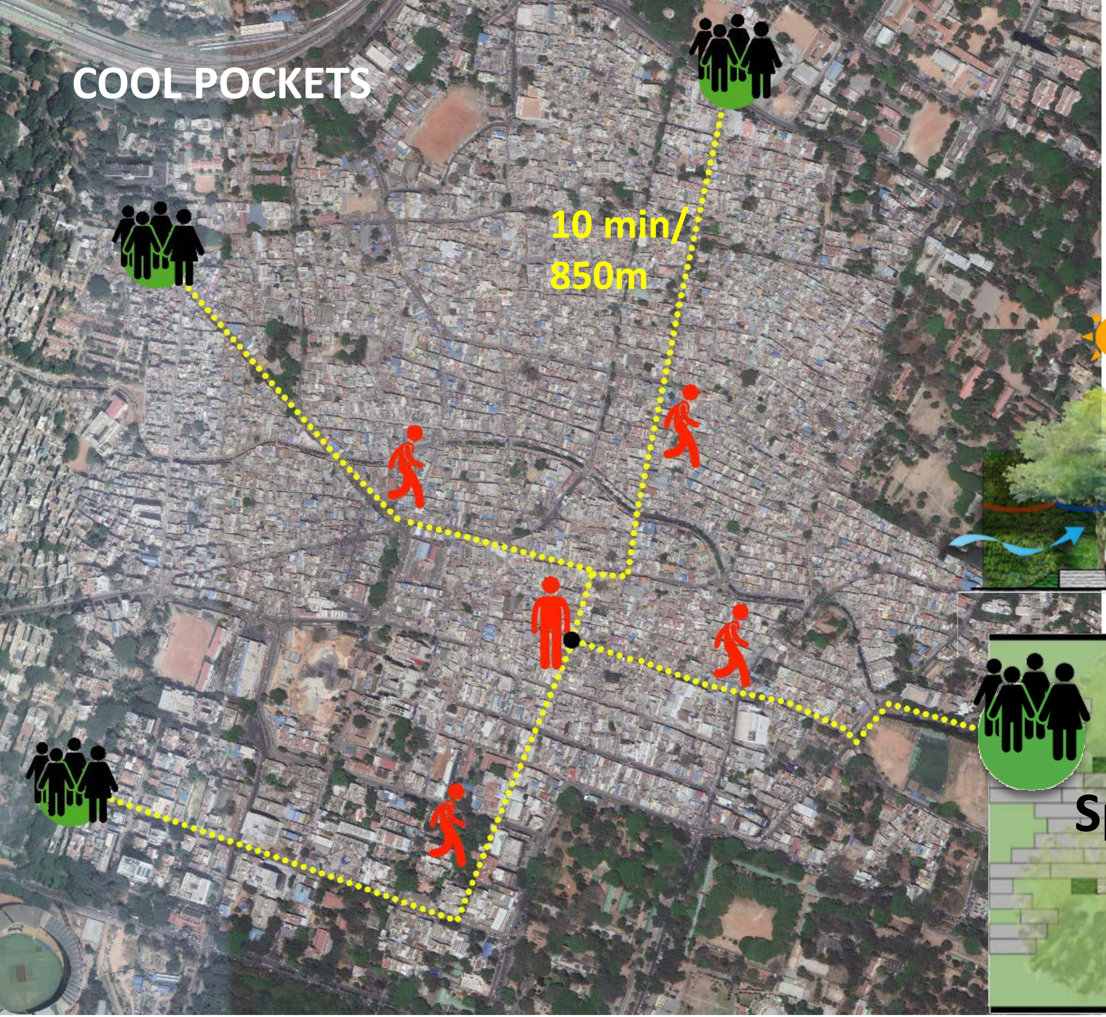




By having 100% shading, adding evapo-transpiration and elevating the wind speed, the number of hours that are in the comfortable range increases. In the best case, no thermal stress is felt for 84%.



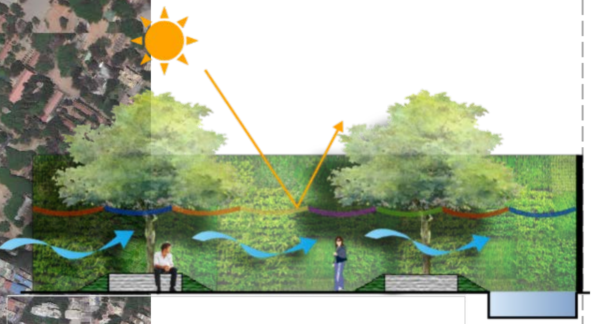
COOL POCKETS

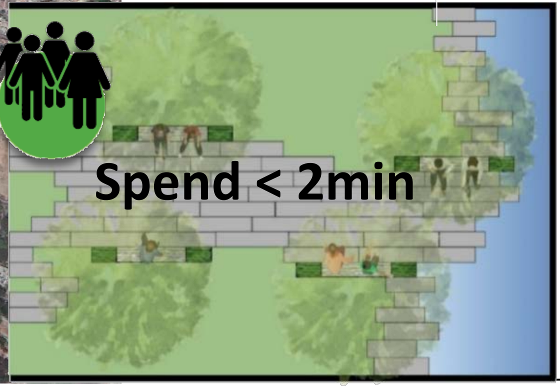


28th April, 14:00

Tair	36.6 °C
RH	36 %
MRT	**30.5 °C**
Clo	0.65
Metabolic Rate	70W/m^2

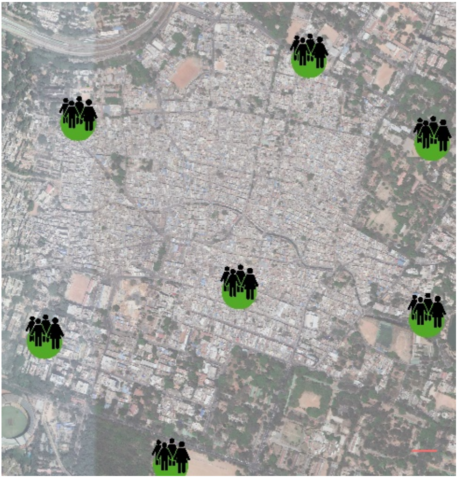
Comfortable in <2mins





The cool pocket has a mean radiant temperature much lower than the surrounding streets. When a pedestrian enters the cool pocket and spends less than 2 minutes in this space, the body regulates the thermal stress, reaching a state of comfort. Having spent 2 minutes standing(70W/m^2) or sitting), a pedestrian can continue walking in comfort.

ENHANCED SCENARIO



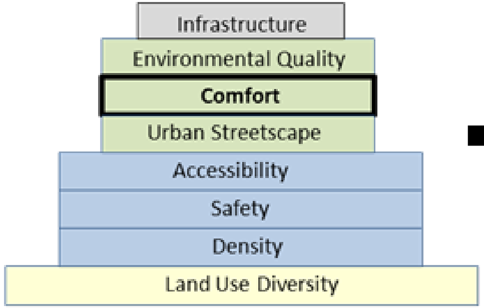
Cool pockets @ 850m → Better: → IMPROVED WALKABILTY

- Urban streetscape
- Environmental quality
- Social interaction and safety
- **Comfort**

If cool pockets were to be designed for the base case scenario, they would be placed at 500m intervals, which is not feasible in a city. In the enhanced scenario, cool pockets are designed at 850m intervals. These cool pockets and better street design provide healthier urban streetscapes, environmental quality, social interaction and safety, and thermal comfort for pedetsrians resulting enriched walkability.

NEXT STEPS

Walkability parameters



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Urban Design

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Target Stakeholder

The next step would be to reach out to non-governmental organizations that work on urban issues. It is essential to establish the understanding that good urban design that address walkability parameters is key for sustainable living in urban areas.

THANK YOU!

$$DISC = 5*(w-0.06)$$

w, the average wettedness of the skin

W= Esk / Emax

Ersw = wrsw Emax

where **wrsw = Asw/AD** the “skin wettedness”, the area of body surface exposed covered by a film of sweat (Asw) as a fraction of the DuBois area.

Andris Auliciems and Steven V. Szokolay (2007) THERMAL COMFORT, Passive and Low Energy Architecture International, Design tools and techniques. Note 3

From the area covered by clothing the sweat will evaporate by diffusion:

$E_{diff} = (1 - w_{rsw})\ 0.06\ E_{max}$

but in the absence of regulatory sweating, if $E_{rsw} = 0$

$E_{diff} = 0.06\ E_{max}$

Generally, for resting subjects, if $40\% < RH < 60\%$ and $DBT < 20°C$

$E_{resp} + E_{diff}$ is about 20-25% of the metabolic rate.

The total skin evaporation, adding the above two terms, is:

$E_{sk} = E_{diff} + E_{rsw} = (0.06 + 0.94\ w_{rsw})\ E_{max}$

or substituting the Emax expression (eq.2.3):

$E_{sk} = 16.7\ (0.06 + 0.94\ w_{rsw})\ h_c\ (p_{sk} - p_a) F_{pcl}$

The evaporation heat loss (E) has three components:

Ediff = due to vapour diffusion through the skin

Ersw = due to evaporation of regulatory sweating from the skin

Eresp= respiration latent heat loss

These components can be estimated in the following way:

Eresp = 0.0173 M (5.87 - pa)

where 5.87 kPa: the saturation vapour pressure at lung temperature: 35°C

pa = vapour pressure of ambient air

The sensible heat loss is:

Cresp= 0.0014 M (34 - ta)

where 34°C is the exhaled air temperature

ta = ambient air temperature (DBT)

hr = radiation conductance (from surface to MRT)
hc = convection conductance (from surface to air)
h = hr + hc
hcl = clothing conductance
he = evaporation heat loss coefficient

The maximum possible evaporative heat loss from the body surface is
Emax= 16.7 hc (psk-pa) Fpcl
where psk = saturation vapour pressure at mean skin temperature
pa = vapour pressure of ambient air (kPa)
Fpcl = vapour permeation efficiency from skin through clothing