Thermal Performance Characteristics of Outdoor Spaces in the Tropics

Towards Mitigating the UHI Effects in Kuala Lumpur, Malaysia

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Large-Scale View Point
Small-Scale View Point

Subjective

Objective
World’s population living in urbanized areas and megacities

2015/2016
50% Urban + 23 megacities

2025
60% Urban + 37 megacities
“Will the real smart city stand up?” Hollands (2008)

Cities and their embraced buildings are repeatedly labeled as smart and green; however, there is not yet a *universal and globally acknowledged definition* of smart and green design...
REGIONAL URBAN EXPANSION 2000-2010

URBAN LAND IN 2000: 106,400 SQ KM

URBAN LAND IN 2010: 134,800 SQ KM

28.4K SQ KM URBAN LAND GROWTH

AVERAGE ANNUAL RATE OF URBAN LAND GROWTH: 2.4%

REGIONAL POPULATION EXPANSION 2000-2010

URBAN POPULATION IN 2000: 579,000,000 PEOPLE

URBAN POPULATION IN 2010: 778,000,000 PEOPLE

200M URBAN POPULATION GROWTH

AVERAGE ANNUAL RATE OF URBAN POPULATION GROWTH: 3%
Complex mathematical modelling

Experiments & Measurements

Urban Climate Simulations

Nigh time temperature do not decrease to the level that it would have!

+ early morning hours

Buildings absorb incoming solar radiation differently than what natural landscape would!

Incoming radiation is absorbed and trapped by the built environment... and will not be released

Cool Roofs

Green Roofs

Vegetation Cover

Permeable Surfaces (evapotranspiration)

Surface Albedo Alteration
- Impact of Diurnal & Seasonal Variations
  (Largest in early morning, night & winter)
- Influence of Synoptic Conditions
- Impact of Topography, large bodies of water, mountain
- Surface vs. Air Temperature UHI

- Other Significant parameters such as:
  - Relative Humidity (RH)
  - Mean Radiant Temperature (MRT)
  - Physiological Equivalent Temperature (PET)

- Exchanges of air and surfaces
7 Zones

4 Basic features: urban structure; urban cover; urban fabric; urban metabolism.

All the aforementioned features are not quantified.

Concept based on their ability to modify the wind, thermal and moisture properties.

Only city environment

Simplified classification of distinct urban forms arranged in approximate decreasing order of their ability to impact local climate (Oke, 2004)
THERMAL CLIMATE ZONE (TCZ)  
(Oke and Stewart, 2006)

TCZ in the city series

TCZ in the mixed series

TCZ in the agricultural series

TCZ in the natural series
The zones are separated using their microscale surface properties including surface roughness height, impervious surface fraction, sky view factor, thermal admittance, albedo and anthropogenic heat flux.

Standardized classification system based on building types and land cover types that enable the researchers to assess and document the heterogeneity in the land cover of study sites.

LCZ Classification System
Variations of Temperature Contrasts

with Viewpoints to the

Local Climate Zones

Stewart and Oke
In 60 of the largest U.S. cities

Average temperature differences between urban and rural stations ranged from: 1°F to more than 7°F

The largest single-day differences between urban and rural stations ranged from: 9°F to 27°F

The top 10 cities with the most intense summer urban heat islands (average daily urban-rural temperature differences) over the past 10 years are:

- Las Vegas (7.3°F)
- Albuquerque (5.9°F)
- Denver (4.9°F)
- Portland (4.8°F)
- Louisville (4.8°F)
- Washington, D.C. (4.7°F)
- Kansas City (4.6°F)
- Columbus (4.4°F)
- Minneapolis (4.3°F)
- Seattle (4.1°F)
Variation of Surface Temperature
Surface heat island or air temperature UHI

Each area = 230 × 230 m
Key Contributors to UHI

Radiation Trapping
• Urban Morphology
• Material’s Thermal Mass

Surface Albedo
• Roof
• Ground Level Surface

Evaporative Cooling Potentials
• Impervious Surfaces
• Urban Greeneries

Anthropogenic Heat
• Traffic
• Building (Density/Population)
• Industry
Rooftop Surface temperature UHI

Green Roof vs Bare Roofs with Impervious Materials
(concert and asphalt)

Retaining the moisture for evaporative cooling plus shading potentials and reducing surface temperature
Retaining the moisture for evaporative cooling plus shading potentials and reducing surface temperature
Physiological Equivalent Temperature (PET)

Location standard time (h)

- PET-Space I (A) vs PET-Space II (A)
- PET-Space I (B) vs PET-Space II (B)

3 Story building

Space I (B)

Space II (B)
Overall Thermal Comfort

65% Local Vs 39% International
The neighborhood of focus in El Monte, California, located in eastern Los Angeles County. At 14:00
CO Control, GR Green roofs, CR Cool roofs, TA Trees added, CP Cool pavement
The Environmental Impacts of Buildings

Leave the world better than you found it
What we do today creates tomorrow
Sustainability as a new way of thinking
21st century cities must be greener and smarter

Rebound effects of ZEBs
Critical review by an integrated team of designers from industry—architect, engineers, clients

Involving INDUSTRY & ACADEMIA
Climate Responsive Design
Climate Responsive Design
Walkability/Bikeability
EFFECTS OF ORIENTATION
EFFECTS OF HEIGHT
EFFECTS OF HEIGHT

Model 6 (4m – 1-storey)  
Model 7 (12m – 3-storey)  
Model 8 (24m – 6-storey)
EFFECTS OF ALBEDO

Model 9 - Albedo 0.3
Model 10 - Albedo 0.55
Model 11 - Albedo 0.93
EFFECTS OF VEGETATION

Models 12 to 16 show different vegetation coverages: 0%, 100%, 25%, 50%, and 75% respectively. The graphs depict air temperature and relative humidity over time, indicating a decrease in air temperature and an increase in relative humidity with increased vegetation coverage.
EFFECTS OF VEGETATION

Model 12
(0% covered by grass/trees)

Model 13
(100% covered by grass)

Model 14
(25% covered by trees)

Model 15
(50% covered by trees)

Model 16
(75% covered by trees)
Comparison of the Temperature Values of the Selected Outdoor Spaces and UM Station

![Study Space 1](image1)
![Study Space 2](image2)
![Study Space 3](image3)
![Study Space 4](image4)
![Study Space 5](image5)
![Study Space 6](image6)
- openness to the sky
- no possibility of shading
- far from the surrounded trees
- less vegetated
- low albedo surface materials
Future Directions

- Interdisciplinary Collaboration
- Green Buildings
- Urban Greening
- Urban Climate Dynamics
- Innovative Solutions
- Human-Environment Interactions
THANK YOU

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