OUTDOOR THERMAL COMFORT AND ADAPTATION FOR PEDESTRIAN IN TOWNS OF MALAYSIA

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Keywords: Outdoor, Pedestrian, thermal comfort, thermal adaptation

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**Outdoor Human Comfort**

Willingness of people staying at outdoor spaces...
A determinant key towards a successful walkable city in hot and humid region...

However, the idea of “COMFORT” is SUBJECTIVE...

Mostly known as “thermal comfort”, refer to a “condition of mind which expresses satisfaction with the thermal environment” (ASHRAE standard 55-66(4)).

A “result of the interaction of physical exchanges, physiological, psychological, social and cultural rights…” (Fabbri, 2015)

Depend on the atmospheric conditions and the characteristics of the physical environment as well as the human’s physiology, psychological and behavioral factors (Middel et al., 2016).
Purpose of Study

- What is outdoor human comfort for the locals?
- How do the design of urban environment that shape outdoor human comfort?
- What theory and methods that are comprehensive enough for conducting such research?

Influence & effectiveness of townscapes

- Microclimate regulation
- Human thermal comfort sensation & perception
- People behavior / response that reflecting human adaptation to local climatic condition
To explore tropical townscape in order to rediscover the mechanism and links between outdoor thermal environments, human comfort and adaptation during hot weather.

- To investigate the features of the townscape that potentially critical to both microclimate and human thermal sensation;
- To examine the effects of the townscape attributes on pedestrian thermal perception and adaptation to hot and humid climate;
- To construct a model to determine both thermal and non-thermal indicators of tropical townscape that stimulates human thermal sensation, perception and adaptation in hot and humid region.

**Aim**

**RO1**

What kind of features of townscape, in terms of open space typology, can yield people’s thermal comfort response, in both positively and negatively?

**RO2**

How the attributes of townscape, in terms of landscape experience, can influence and stimulate the pedestrian thermal perception and adaptation to hot and humid climate?

**RO3**

What are the factors/indicators of outdoor thermal comfort and their influences to human thermal sensation, perception and adaptation in hot and humid region?
Challenges of Study
(problem statement)

The topic of **human outdoor thermal comfort** is still LESS being questioned and explored...

**Theory from an outdoor perspective is less viewed:**

Current outdoor thermal comfort studies have to rely on existing thermal theories and indexes but they are not comprehensive to explain outdoor comfort condition

(Brager & de Dear, 1998; Höppe, 2002; Chen & Ng, 2012; Andeau, 2013)

**Current outdoor thermal studies are more inclined to outdoor microclimate studies:**

i.e urban heat island, vegetation effects, urban geometry effects

**Poor knowledge on thermal adaptation mechanism:**

- Outdoor thermal comfort in fact is hard to be achieved passively in hot region (Ali-toudert & Mayer, 2006).
  The availability of thermal adaptive opportunities in outdoor context is still in exploration.
Research Gap

Most existing thermal comfort theories, models and methods have failed to predict / describe the actual thermal sensation accurately.

Contexts of study & Research area

Argument on the applicability and feasibility of applying current thermal comfort theories and indexes into outdoor thermal comfort studies. From a thermal steady state into the dynamic and changeable thermal condition of outdoor environment.

Variables/Indicators used

Doubt on the thermal research trend that highly depend on pure thermal indicators, in which only consider several climatic and human factors, which are: air temperature, mean radiant temperature, air velocity, relative humidity, human clothing, metabolism
Research Gap

Differences between HUMAN COMFORT in INDOOR & OUTDOOR

**INDOOR Thermal Comfort** vs **OUTDOOR Thermal Comfort**

<table>
<thead>
<tr>
<th>Steady/Stable</th>
<th>Context</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Since 1940s: Gagge &amp; Bazett; Fanger; Mayer &amp; Höppe; Brager &amp; de Dear; Humphreys &amp; Nicol</td>
<td>History: Höppe, Nikolopoulou, Lin</td>
<td></td>
</tr>
<tr>
<td>Tend to Passive</td>
<td>Intention</td>
<td>Tend to Active</td>
</tr>
<tr>
<td>Yes</td>
<td>Theory/model</td>
<td>Generally refer to indoors</td>
</tr>
</tbody>
</table>

### Variable/Indicator used
- Air temperature
- Mean radiant temp.
- Air velocity
- Relatively humidity
- Clothing
- Metabolism (activities)

### Generally refer to indoors
- Physiological
- Behavioral adjustment of the body heat-balance
- Psychological.

### Approach of thermal sensation & adaptation
- Thermal neutrality; Comfort range

### Ideal
- Unclear
The study tries to expand the area of study to the other areas like psychology and socio-culture, in the lens of landscape experience.

Through the attributes offered by the outdoor spaces, particularly in the context of town setting, this study assumes people tend to respond and adapt psychologically to the outdoor thermal environment.

Aspects of this assumption involve:

- the influence of individual experiences on thermal comfort range,
- the multi-sensory impacts of outdoor to a person’s thermal comfort; and
- the socio-cultural effects to an individual thermal response.
Literature review
Trends of Comfort Studies

Examples of Works & Scholars:
- Ahmed 2003
- Ali-toudert & Mayer 2006
- Bowler et al 2010
- Hwang, Lin & Matzarakis 2011
- Andreou 2013
- Klemm et al 2015
- Sravanit & Auttarat 2015

Local Works & Scholars:
- Shahidan, Shaileh & Shariff 2007
- Shahidan & Jones 2008
- Shahidan et al. 2012
- Nasir, Ahmad & Ahmed 2012
- Nasir et al 2015
- Manteghi, Lamit & Remaz 2015
- Manteghi et al. 2016
- Saito, Said & Shinozaki 2017

Theme:
- Thermal Adaptive mechanism
- Psychological mechanisms
- Outdoor Thermal Comfort Theory

Seminal Works & Scholars:
- Nagara 1996
- Brager & de Dear 1998
- Höppe 2002
- Lin & Matzarakis 2008: tourism climate and thermal comfort
- Lin 2009: Thermal perception, adaptation and attendance
- Nikolopoulou, Baker & Steemers 2001: human parameter for outdoor comfort
- Nikolopoulou & Steemers 1999 & 2003: Psychological adaptation for outdoor comfort
- Knez et al 2009: Psychological mechanisms

Urban Climate Measurement & Thermal Comfort Assessment

Theme:
- Outdoor Thermal Comfort Theory
- Outdoor thermal comfort indices / indexes
- Predicted thermal comfort model development

Seminal Works & Scholars:
- Gagge, Burton & Bazett: clo & met units; thermal indices
- Fanger: PMV & PPD

Theme:
- Thermal Comfort Theory
- Thermal Comfort indices / indexes
- Predicted thermal comfort model development

Seminal Works & Scholars:
- Vasilikou & Nikolopoulou 2013, 2015: Thermal walk/Thermal notations
- Lenzholzer, Klemm & Vasilikou 2015, 2016: thermo-spatial perception
- Nicol & Roaf, 2017: Rethinking thermal comfort
- Santos Nouri & Costa, 2017: Place Diagram

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- Thermal Comfort Theory
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Situation of Study: Relevant Themes and Subjects

- Microclimate
  - Urban Form
  - Air temperature
  - Radiant temperature
  - Wind
  - Human-biometeorology
  - Metabolism rate (activities level)
  - Clothing
  - Body built (weight and Height)
  - Gender
  - Skin temperature
  - Heat tolerance level
  - Behavior adjustment
  - Time of exposure
  - Willingness to thermal discomfort

- Human Thermal Physiology
  - Human Perception
    - Perceived control
    - Intention of activities
    - Environmental stimulation
    - Time of exposure
    - Willingness to thermal discomfort
    - Socio-economic background
    - Ethnic culture background
  - Thermal Expectation & Preference
  - Past experience

- Visual comfort
  - Naturalness
  - Color
  - SVF

- Acoustic comfort
  - Intention of activities

- Spatial perception
  - Orientation
  - Material
  - Aspect ratio (H/W)
  - Cloudlessnes s
  - Solar radiation

- National – geographic location (latitude)

- Thermal quantities

- Non-thermal quantities
Underpinning theories

The parameter of psychological adaptation: the interrelationship
(Source from: Nikolopoulou and Steemers, 2003)
Underpinning theories

The urban space typology
(Source: Sandalack & Uribe, 2010)

The conceptual model of sociocultural system.
(Source: https://en.wikipedia.org/wiki/Sociocultural_system)
Underpinning theories

Pyramid of needs of pedestrian in public spaces.
(Source: Amoroso, Castelluccio & Maritano, 2012)

The “Place Diagram” by the PPS. (Source: PPS, 2003).
Study Framework

The naturalness and climate cultural practices derived from urban space typology.
Study Framework

The influencing factors to thermal psychological response

**Pre-condition for outdoor thermal assessment**

**Pedestrian needs**
- Attractiveness
- Comfort
- Convenience
- Reliability
- Safety
- Health/Mobility

**HUMAN Indicators**

**ENVIRONMENTAL Indicators**
- Naturalness (ratio between built form, public realm and landscapes)

**SOCIO-CULTURAL Indicators**
- Climate cultural practices

**Human perception**

**Human senses**

**THERMAL PSYCHOLOGICAL RESPONSE**
Study Framework

The flow of thermal comfort and adaptation
### Methodology

<table>
<thead>
<tr>
<th>Research objectives</th>
<th>Determinant</th>
<th>Indicators</th>
<th>Methods</th>
<th>Tools/Analysis</th>
<th>Outcomes</th>
</tr>
</thead>
</table>
| **RO1**             | Spatial pattern and properties| • Built-up area  
• Open spaces  
• Street  
• Landscape elements | • Mapping  
• Field notes | • 1 set portable weather station  
• 1 360 degree camera | Thermal factors of Outdoor Thermal Comfort |
|                     | Microclimate                 | • Air temperature  
• Mean radiant temperature  
• Wind velocity  
• Relative humidity | • Site thermal measure | • Software: ENViMet & Rayman |                                          |
|                     | PET                          | • Climatic data  
• Human clothing and metabolic rate | • Simulation                  |                                          |                                          |
| **RO2**             | Human experience             | • Human  
• Environmenta: naturalness  
• Socio-culture: climate cultural practices & norms | • Observation through Photography  
• Mapping  
• Questionnaire  
• Interview | • 1 360 degree camera  
• Software: SPSS or Nvivo | Non-Thermal factors of Outdoor Thermal Comfort: |
| **RO3**             | Human comfort                | • Thermal factors  
• Non-Thermal factors | • Structural equation modeling (SEM) | • Software: SmartPLS | Assessment Model of Outdoor Thermal Comfort |
Flow of Study

Proposed Outline

Stage 1

Introduction
Background, Problem statement, Objectives, Scope of study

Stage 2

Literature Review
Trend of studies, Research foundation, Research gap, Theoretical framework formulation

Stage 3

Research Methodology
Conceptual framework formulation (Model), Site context and scale, Design of parameters and methods, Tools and software used

Stage 4

Fieldworks
Site thermal measurement, observation, questionnaire & interviews

Stage 5

Results, Analysis and Discussion
Findings based on objectives

Conclusion
- An assessment model of pedestrian outdoor thermal comfort and adaptation in hot and humid region.
- Contribution, limitations & recommendation
Anticipated Results

Outdoor human comfort is a collective achievement.

**Environmental aspect**
- Different function of spaces generate different adaptive practices for thermal comfort.

**Existing Climatic aspect**

**Human aspect** (including existing human factor)
- Multisensory experience for outdoor thermal comfort
- Satisfaction of pedestrian experience would affect their thermal comfort by psychologically as well.

**Socio-cultural aspect**
- Regional culture shapes human comfort

*Regional culture shapes human comfort*
Anticipated Results

Outdoor human comfort assessment model is not a one-way process.

- **Thermal Comfort**
  - Physiology
  - Psychological and behaviors
  - Thermal adaptation
    - Physical adaptation
    - Physiological adaptation
    - Psychological adaptation
  - Thermal perception
    - Experience
      - Time of exposure
      - Environmental Stimulation
      - Perceived Control
  - Human perception
  - Human senses (multisensory)
  - Climate-cultural practices & norms
    - Naturalness
  - Pedestrian needs (Human)
Summary

• Outdoor thermal comfort analysis cannot merely dependence on existing thermal models, methods and theories that originated from indoor setting.
• The proposal suggested perhaps the focus should be more placed on exploring the non-thermal determinants of thermal comfort, meanwhile consider also more physical thermal determinant at outdoors like shade/solar access.
• Psychological outdoor thermal comfort are highlighted.

Significances of Study

• The final outcome is expected to develop a practical model for assessing outdoor thermal comfort, particularly for hot regions.
• The result can also be a reference for urban professionals like planners, landscape architects and policy makers during the process of design and planning for outdoor public spaces.
• With a more humanized design and planning in pedestrian system, it also helps the implementation of People-Oriented Cities. Such implementation will effectively mitigate the urban warming effects as well.
## Milestone

### Proposed Research Planning and Schedule (Gantt chart)

<table>
<thead>
<tr>
<th>Schedule</th>
<th>UTM (MALAYSIA)</th>
<th>SIT (TOKYO)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>2017/2018-01</td>
<td>Fall semester 2018</td>
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<tr>
<td>2017/2018-02</td>
<td>Fall semester 2018</td>
<td>Spring semester 2019</td>
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<td>Semester 1</td>
<td>Semester 2</td>
<td>Semester 1</td>
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<tr>
<td><strong>Formation of Research</strong></td>
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<tr>
<td>Literatures review</td>
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<td>Analysis of existing study</td>
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<td>Submission of application</td>
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<td>Entrance examination</td>
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<td><strong>Data Collection &amp; Analysis</strong></td>
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<td>Pilot study</td>
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<td>Fieldwork checklist</td>
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<tr>
<td>Data collection</td>
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<tr>
<td>Analysis &amp; evaluation</td>
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<td><strong>Thesis Writing</strong></td>
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<td>Writing up</td>
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<td>Pre-defense &amp; final defense</td>
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<td>Final editing of thesis</td>
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<td>Final thesis submission</td>
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<tr>
<td>Conference / Publication</td>
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References

Key Authors


THANK YOU SO MUCH...