Urban Infrastructure Anatomy

Heat Exposure and Transit Use
Travel Behavior and Infrastructure

25 April 2017
Temperature Change (°F)
Relative to 1970-1999

NASA, 800ppm CO₂ by 2100, https://www.youtube.com/watch?v=39cBqY1sszY
Maricopa County Heat-related Mortality and Morbidity

Eisenman et al. (2016)
“A community’s vulnerability to extreme heat can be understood as a function of its heat exposure, population characteristics and adaptive capacity.”

Eisenman et al. (2016)
Transit necessitates environmental exposure!
What can we do?
Joint Class Venture

VERTICAL INFRASTRUCTURE

Construction Methods, Materials, & Equipment

HORIZONTAL INFRASTRUCTURE

Urban Infrastructure Anatomy

CONSTRUCTION

CIVIL, ENVIRONMENTAL, & SUSTAINABLE ENGINEERING

GEOGRAPHY & PLANNING

SCHOOL OF SUSTAINABILITY
URBAN INFRASTRUCTURE ANATOMY

SPRING 2017

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Heat Exposure and Transit Use: Travel Behavior and Infrastructure
**Travel Survey**

**TEMPE TRANSIT SURVEY**

ASU Students request your help in understanding transit riders' experiences of heat at Tempe transit stops. Please complete the following questions to the best of your ability. Thank you for your time.

1. **How did you reach this transit stop?**
   - □ Walk
   - □ Bike
   - □ Skateboard
   - □ Car
   - □ I transferred from another line
   - □ Other: __________

2. **How long do you typically wait at a transit stop?**
   - □ 1 – 5 minutes
   - □ 6 – 10 minutes
   - □ 11 – 20 minutes
   - □ Over 20 minutes

3. **How long did it take you to reach this transit stop?**
   - □ 1 – 5 minutes
   - □ 6 – 10 minutes
   - □ 11 – 20 minutes
   - □ Over 20 minutes
   - □ I transferred from another line

4. **Do you change the way you travel when it gets hot?**
   - □ Don't change behavior
   - □ Earlier/later travel
   - □ Bring umbrella
   - □ Bring water or bring more water
   - □ I try to get cover in shade on the way
   - □ Go to another stop
   - □ Other: __________

5. **How do you keep cool while you wait?**

6. **Is there a temperature at which you would be uncomfortable waiting at or traveling to a transit stop, and if so what is it?**
   - □ 80 °F (27 °C)
   - □ 90 °F (32 °C)
   - □ 100 °F (38 °C)
   - □ 110 °F (43 °C)
   - □ Over 110 °F (Over 43 °C)
   - □ No / I don't have a choice.

7. **Do any of these elements make you feel cooler? Select all that apply.**
   - □ Nearby Trees
   - □ Nearby Grass
   - □ Nearby Shrubs
   - □ Nearby Water
   - □ Benches
   - □ Shade Structures
   - □ Other: __________

8. **What is your gender?**
   - □ Male
   - □ Female

9. **What is your age?**
   - □ 18 – 24
   - □ 25 – 34
   - □ 35 – 44
   - □ 45 – 54
   - □ 55 – 64
   - □ 65 or older

10. **What is your household income?**
    - □ Below $20,000
    - □ $20,000 – $30,000
    - □ $30,000 – $40,000
    - □ $40,000 – $60,000
    - □ $60,000 – $80,000
    - □ $80,000 – $100,000
    - □ $100,000 or over
Travel Survey Results

Do any of these elements make you feel cooler?
(91 responses)

- Nearby Trees: 0.9
- Nearby Grass: 0.3
- Nearby Shade: 0.1
- Nearby Water: 0.3
Travel Survey Results

What is your age? (91 responses)

- 18-24: 50.5%
- 25-34: 25.3%
- 35-44: 12.1%
- 45-54: 6.1%
- 55-64: 4.5%
- 65 or older: 3.3%
- Other: 0.0%
Travel Survey Results

How long did it take you to reach this transit stop? (91 responses)

- 1-5 minutes: 47.3%
- 6-10 minutes: 34.1%
- 11-20 minutes: 13.2%
- Over 20 minutes
- I transferred from another line
- Other
Travel Survey Results

How long do you typically wait at a transit stop? (91 responses)

- 1-5 minutes: 39.6%
- 6-10 minutes: 44%
- 11-20 minutes: 14.3%
- Over 20 minutes
- Other
Transit Behavior
### Survey Walk + Wait Time Results

<table>
<thead>
<tr>
<th>Wait Time</th>
<th>Walk Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-5 minutes</td>
</tr>
<tr>
<td>1-5 minutes</td>
<td>7</td>
</tr>
<tr>
<td>6-10 minutes</td>
<td>23</td>
</tr>
<tr>
<td>11-20 minutes</td>
<td>13</td>
</tr>
<tr>
<td>Over 20 minutes</td>
<td>-</td>
</tr>
</tbody>
</table>
Wait times + Ridership
Greenery + Ridership
Shade Level + Ridership
What stops/routes to focus on?

- Rio Salado & Hardy
- Priest & 11th
- Hardy & Elna Rae
Exposure
## Experimental design

A photo collage of all of the stops we visited to visually demonstrate the variety of stop configurations we sampled.

<table>
<thead>
<tr>
<th>Stop component</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement</td>
<td>Concrete, brick, asphalt</td>
</tr>
<tr>
<td>Seats</td>
<td>Concrete, metal, plastic</td>
</tr>
<tr>
<td>Landscaping</td>
<td>Xeric (rocks/dirt), mesic (grass)</td>
</tr>
<tr>
<td>Shading</td>
<td>Shade structures, direct tree shading, indirect tree shading</td>
</tr>
</tbody>
</table>
Heat Exposure and Transit Use: Urban Infrastructure Anatomy

- 133°F
- 118°F
- 112°F
- 100°F
- 89°F
- 85°F
Results: Impacts of shade type on surface temperatures

Sampling time: March & April 2017
Largest temperature difference: 69.1 °F – 124 °F
Results: Impacts of shade type on thermal characteristics

Shade type is the dominant control for surface and air temperatures at transit stops

- $R^2 = 0.69$
- Significant relationship to surface temperature ($p<.001$)
- Inconclusive relationship to air temperature
Results: Heat perceptions versus actual field data

77% of survey respondents perceived that trees provided significant heat relief.

Field measurements indicated tree shading provided on average greater heat mitigation versus built shade structures.
Results: Heat perceptions versus actual field data

75% of survey respondents indicated heat-related discomfort at or below 110°F
Results: Heat perceptions versus actual field data

75% of survey respondents indicated heat-related discomfort at or below 110°F
Mitigation
Heat Risk Assessment

Purpose: To combine the previously presented Survey Walk + Wait Time Results with the Impacts of shade type on surface temperatures results and form them into a tool to identify the most at risk bus stops.
Applying the Heat Risk Assessment: Transit Stop-University Dr. & College Ave.

Average Wait Time – 11-20 Minutes
Average Walk Time – 11-20 Minutes
Combined Risk level = 6
Averaged Risk Level (Divide by total number of values) = 6/2 = 3
Overall Risk Level = 3 out of 4

Concrete (Shaded) – 1
Concrete (Unshaded) – 3
Seat (Unshaded) – 3
Combined Risk Level = 7
Averaged Risk Level (Divide by total number of values) = 7/3
Overall Risk Level = 2.33 of 4
Result:

Combine the numbers = 3 out of 4 & 2.33 out of 4
Combined Overall Risk = 5.33 out of 8

Recommendations:

1. Valley Metro expand the survey size and the sample of thermal images

2. Apply the Heat Risk Assessment Methodology to identify the most at risk stops
Mitigation Strategies

- Cool roof
- Cool Pavement
- Green roof
- Green walls
- Green pavement
- Water fountain
- Solar panels
- Trees
- Grass
- Shrubs
- Pedestrian amenities
- Open air misting System
- Cooling centers
- Public chill water system
- Water detention – ponds

- Wetlands
- Open areas for parks
- District heating and cooling
- Combined heat and power or co-generation systems
- Enhanced transit connectivity
- Restructuring traffic and transportation
- Using renewable energy and appliances
- Public education
- Early warning systems
- Community-based outreach programs

**Less Maintenance-**
- Cool pavement

**Efficiency-**
- Solar panels

**Sustainability-**
- Vegetation
<table>
<thead>
<tr>
<th>Category</th>
<th>Infrastructure Name</th>
<th>Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urban Cover</strong></td>
<td>Grass</td>
<td>Material: 0.05¢/ft² &amp; Labor: $30/hr</td>
</tr>
<tr>
<td></td>
<td>Shrub</td>
<td>Material: $10<del>16.65/gallon Planting: $106</del>2423/tree</td>
</tr>
<tr>
<td></td>
<td>Tree</td>
<td>Material: $7.58<del>28/gallon Planting: $106</del>2423/tree</td>
</tr>
<tr>
<td><strong>Urban Fabric</strong></td>
<td>Cool Pavement</td>
<td>$2 - 2.50/ft²</td>
</tr>
<tr>
<td></td>
<td>Green Pavement</td>
<td>$1.5 - 5.74/ft²</td>
</tr>
<tr>
<td></td>
<td>Green Wall</td>
<td>$90 - 135/ft²</td>
</tr>
<tr>
<td><strong>Urban Metabolism</strong></td>
<td>Green Roof</td>
<td>$10/ft²</td>
</tr>
<tr>
<td></td>
<td>Solar Panel</td>
<td>$2.87-3.85 per watt Labor: $0.44 per watt</td>
</tr>
<tr>
<td></td>
<td>Water Fountain</td>
<td>Material: $60<del>1800/each Labor cost: $320</del>520/each installation Excavation: $0.047~2.28/sqrt</td>
</tr>
</tbody>
</table>
Heat Exposure and Transit Use: Urban Infrastructure Anatomy

- Shading
  - Trees
  - Shelters
  - Awnings

Phoenix, AZ

- Green Infrastructure
  - Green walls
  - Green roofs
  - Vegetated pavement

Hampstead, UK
Example of Applied Strategies

Tempe, AZ Priest & 11th St

Asian Art Museum of San Francisco
Future Innovation Possibilities

- Frequency Based Maps
- Signage To Cooling Stations
- Digital Signage
- Increasing Maintenance
Policy-Funding

Funding Sources Come From Many Different Sources, For Many Different Projects

Funding Sources Could Include:
- Special Tax Districts (Hyper Local)
- City Governments
- Bonds & Voter Approved Initiatives (City or Countywide)
- County Governments
- State & Federal Governments
- Private Funds
  - Willing Businesses
  - Health-Oriented Advocacy Groups
Questions?

urbansustainability.lab.asu.edu