ASU

Urban Infrastructure Anatomy

Civil, Environmental, & Sustainable Engineering

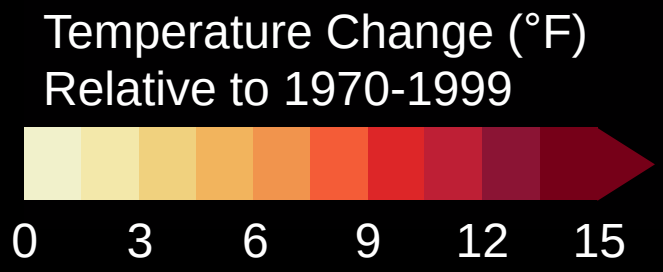
Geography & Urban Planning

School of Sustainability

Heat Exposure and Transit Use

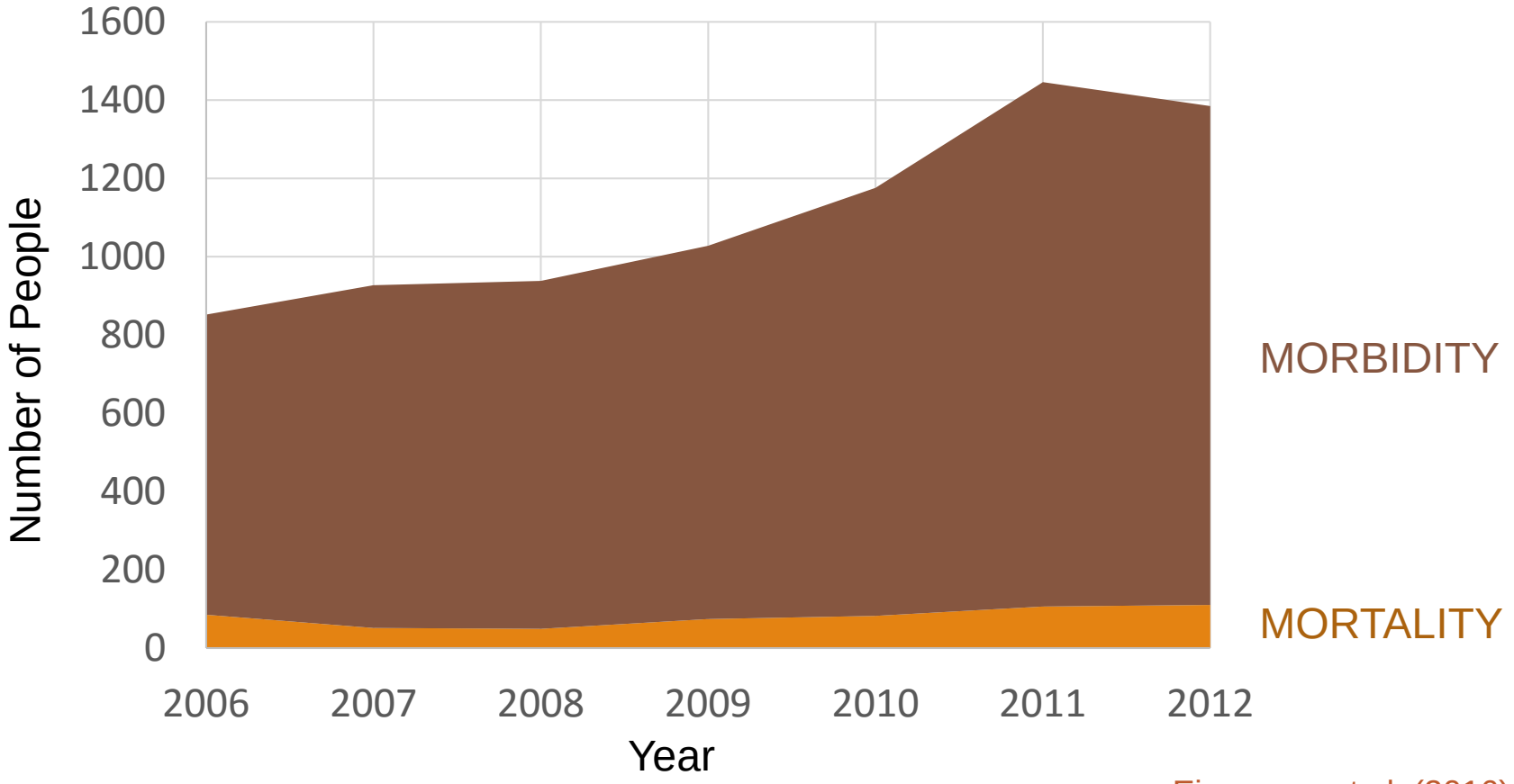
Travel Behavior and Infrastructure

25 April 2017



NASA, 800ppm CO_2 by 2100, https://www.youtube.com/watch?v=39cBqY1sszY

Maricopa County Heat-related Mortality and Morbidity

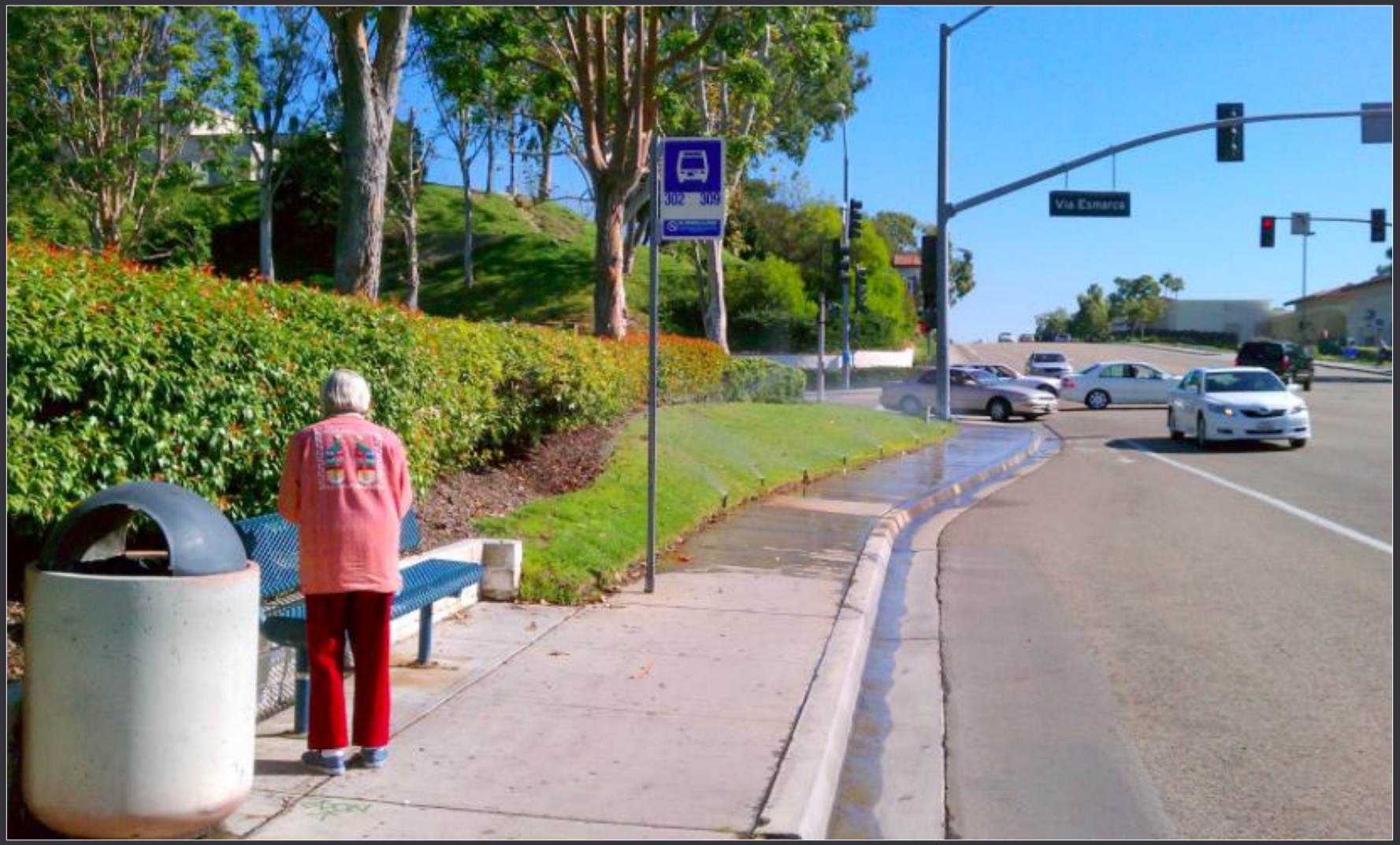


Eisenman et al. (2016)

"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

Construction Methods, Materials, & Equipment

- CONSTRUCTION

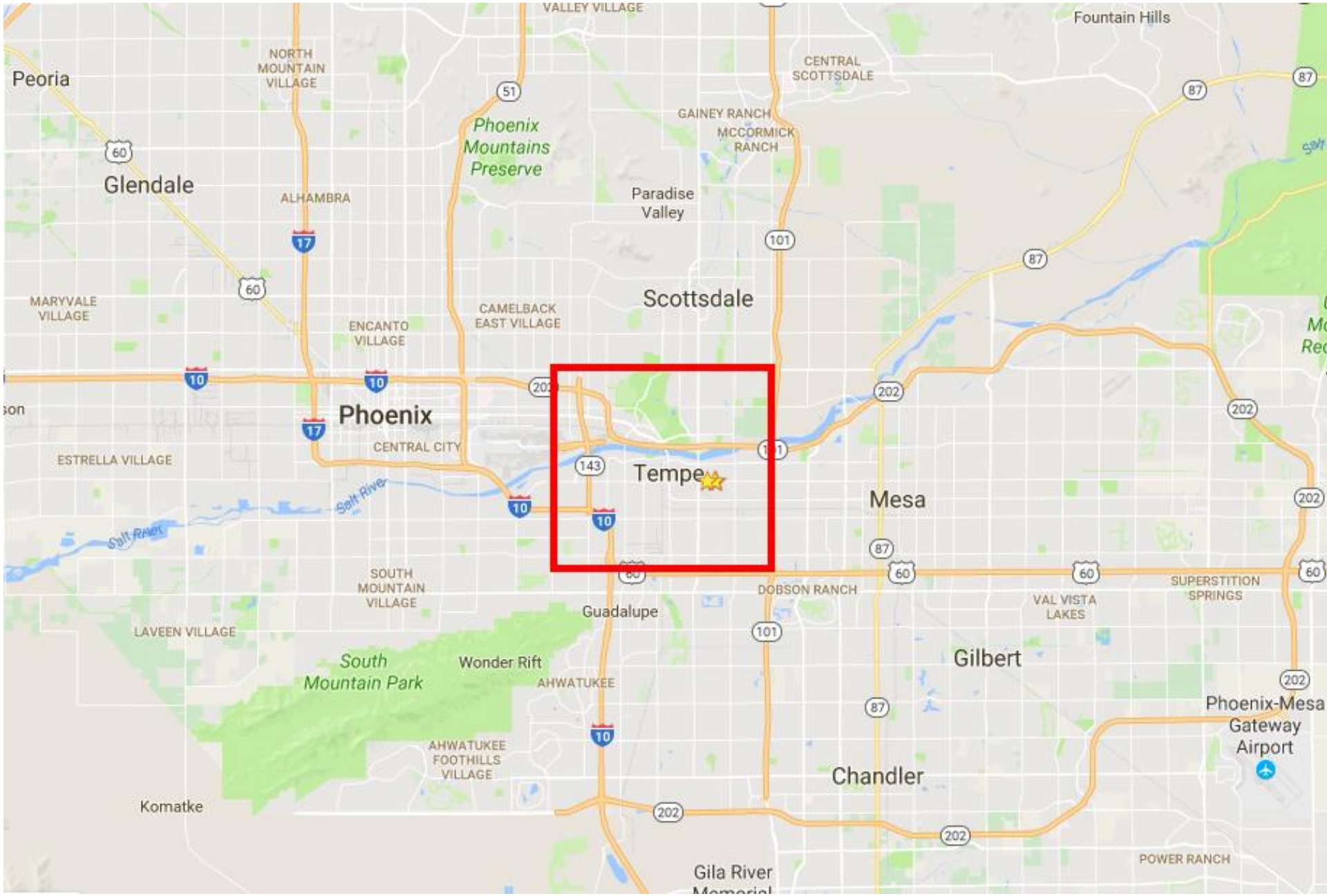
Urban Infrastructure Anatomy

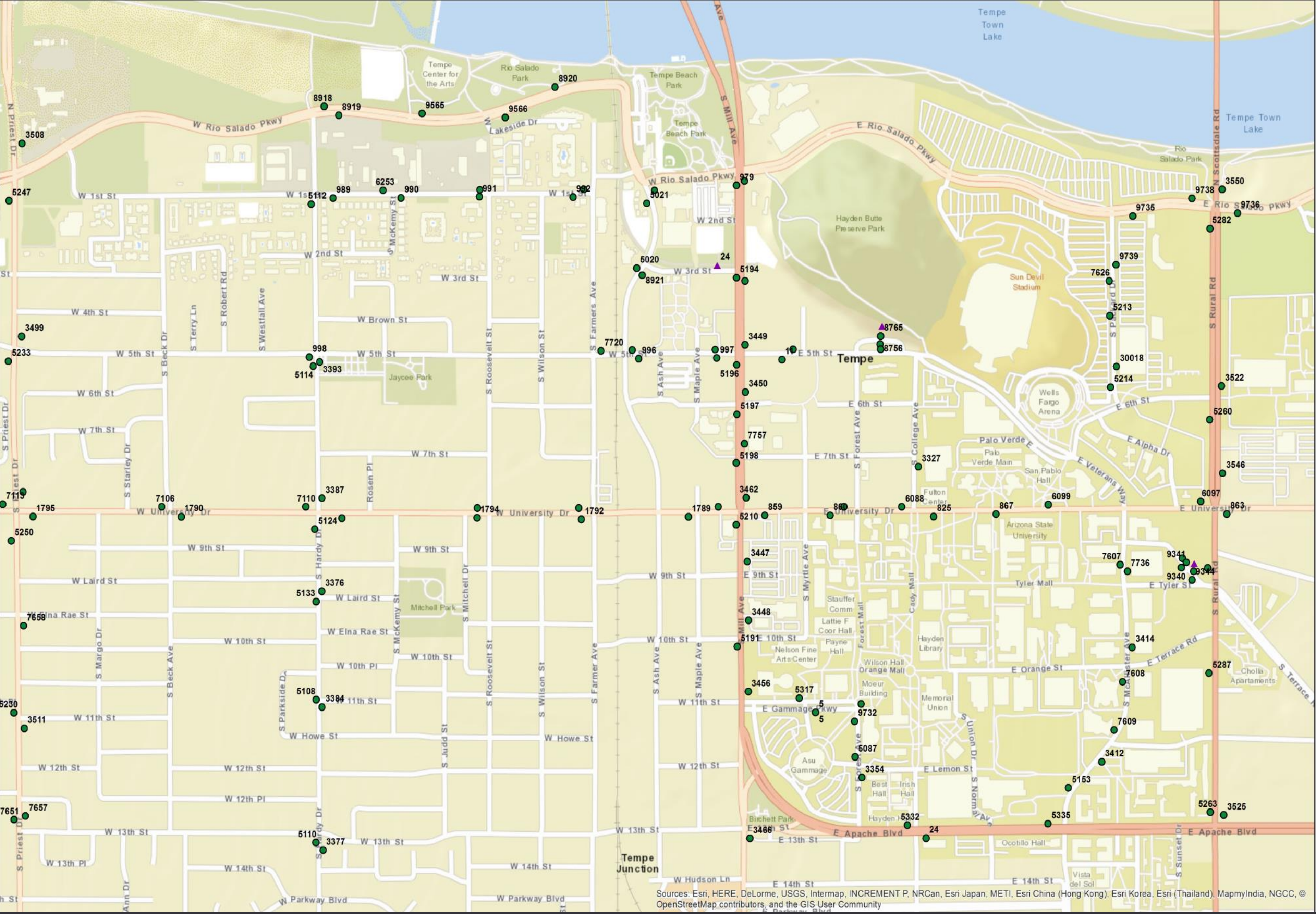
- CIVIL, ENVIRONMENTAL, & SUSTAINABLE ENGINEERING
- GEOGRAPHY & PLANNING
- SCHOOL OF SUSTAINABILITY

URBAN INFRASTRUCTURE ANATOMY

SPRING 2017

- Jake Arishi (SSEBE)
- Habib Azarabadi (SSEBE)
- Rio De Leon (SGSUP+SPA)
- Kevin Dwyer (SFIS)
- Yuliya Dzyuban (SOS)
- Amr Fenais (SSEBE)
- Nagelle Fernandes (SOS)
- Andres Gonzalez (SOS)
- Chris Hoehne (SSEBE)
- Joseph Mueller (SGSUP)
- Suhas Podduturi (SSEBE)
- Nokwanda Ramatheko (SGSUP)
- Jordan Rodriguez (SSEBE)
- Joshua Rogers (SGSUP)
- Sam Rogers (SGSUP+SPA)
- Chris Sanchez (SOS)
- Kristian Santana (SSEBE)
- Rachael Sherman (SSEBE)
- Hunter Venne (SSEBE)
- Andrew Wills (TDS)
- Jiang Xie (SSEBE)
- Sai Yellasiri (SSEBE)
- Pengfei Zhang (SSEBE)
- Madeline Sawyer (SSEBE)
- Joseline Castaneda (SGSUP)


Fountain Hills
Peoria
NORTH MOUNTAIN VILLAGE
CENTRAL SCOTTSDALE
GAINEY RANCH
MCCORMICK RANCH
Phoenix Mountains Preserve
Glendale
ALHAMBRA
Paradise Valley
MARYVALE VILLAGE
CAMELBACK EAST VILLAGE
Scottsdale
ENCANTO VILLAGE
Phoenix
CENTRAL CITY
ESTRELLA VILLAGE
Tempe
Salt River
Mesa
SOUTH MOUNTAIN VILLAGE
DOBSON RANCH
VAL VISTA LAKES
SUPERSTITION SPRINGS
Guadalupe
LAVEEN VILLAGE
South Mountain Park
Wonder Rift
AHWATUKEE
Gilbert
Phoenix-Mesa Gateway Airport
AHWATUKEE FOOTHILLS VILLAGE
Chandler
Komatke
POWER RANCH
Gila River



Tempe Town Lake
Tempe Center for the Arts
Rio Salado Park
Tempe Beach Park
W Rio Salado Pkwy
E Rio Salado Pkwy
W Lakeside Dr
Hayden Butte Preserve Park
Sun Devil Stadium
Wells Fargo Arena
Palo Verde
Palo Verde Main
San Pablo Hall
Fulton Center
Arizona State University
Tempe
Jaycee Park
Mitchell Park
Stauffer Comm
Lattie F Coor Hall
Payne Hall
Nelson Fine Arts Center
Wilson Hall
Orange Mall
Moeur Building
Memorial Union
Hayden Library
Asu Gammage
Best Hall
Irish Hall
Birchett Park
Ocotillo Hall
Vista del Sol
Cholla Apartaments
Tempe Junction
W 1st St
W 2nd St
W 3rd St
W 4th St
W Brown St
W 5th St
E 5th St
W 6th St
E 6th St
W 7th St
E 7th St
W University Dr
E University Dr
W 9th St
E 9th St
W Laird St
W Elna Rae St
W 10th St
W 10th Pl
E 10th St
W 11th St
W Howe St
W 12th St
W 12th Pl
W 13th St
E 13th St
W 13th Pl
W 14th St
E 14th St
W Hudson Ln
W Parkway Blvd
E Apache Blvd
E Lemon St
E Orange St
E Tyler St
Tyler Mall
E Gammage Pkwy
E Terrace Rd
E Alpha Dr
E Veterans Way
S Terrace
N Priest Dr
S Priest Dr
S Beck Dr
S Terry Ln
S Robert Rd
S Westfall Ave
S Starley Dr
S Hardy Dr
S McKemy St
S Rosen Pl
S Roosevelt St
S Mitchell Dr
S Wilson St
S Farmers Ave
S Ash Ave
S Maple Ave
S Mill Ave
S Myrtle Ave
S Forest Ave
S College Ave
Cady Mall
Forest Mall
S Union Dr
S Normal Ave
S Rural Rd
N Scottsdale Rd
S Sunset Dr
S Margo Dr
S Parkside Dr
S Judd St
S Mc Allister Ave
3508 5247 8918 8919 9565 9566 8920 5112 989 6253 990 991 992 5021 979 9738 3550 9735 9736 5282
5020 24 8921 5194 9739 7626 5213 3499 5233 998 5114 3393 7720 996 997 3449 5196 8765 8756 30018 5214 3522
3450 5197 5260 7757 5198 3327 3546 7113 1795 7106 1790 7110 3387 1794 1792 1789 3462 5210 859 880 6088 825 867 6099 6097 863
5250 5124 3447 7607 7736 9341 9340 9344 3376 5133 7658 3448 5191 3414 5287 7608
5230 3511 5108 3384 3456 5317 9732 7609 5087 3354 3412 5153 7651 7657 5110 3377 3466 5332 24 5335 5263 3525
Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

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 that is more shaded
- ☐ 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

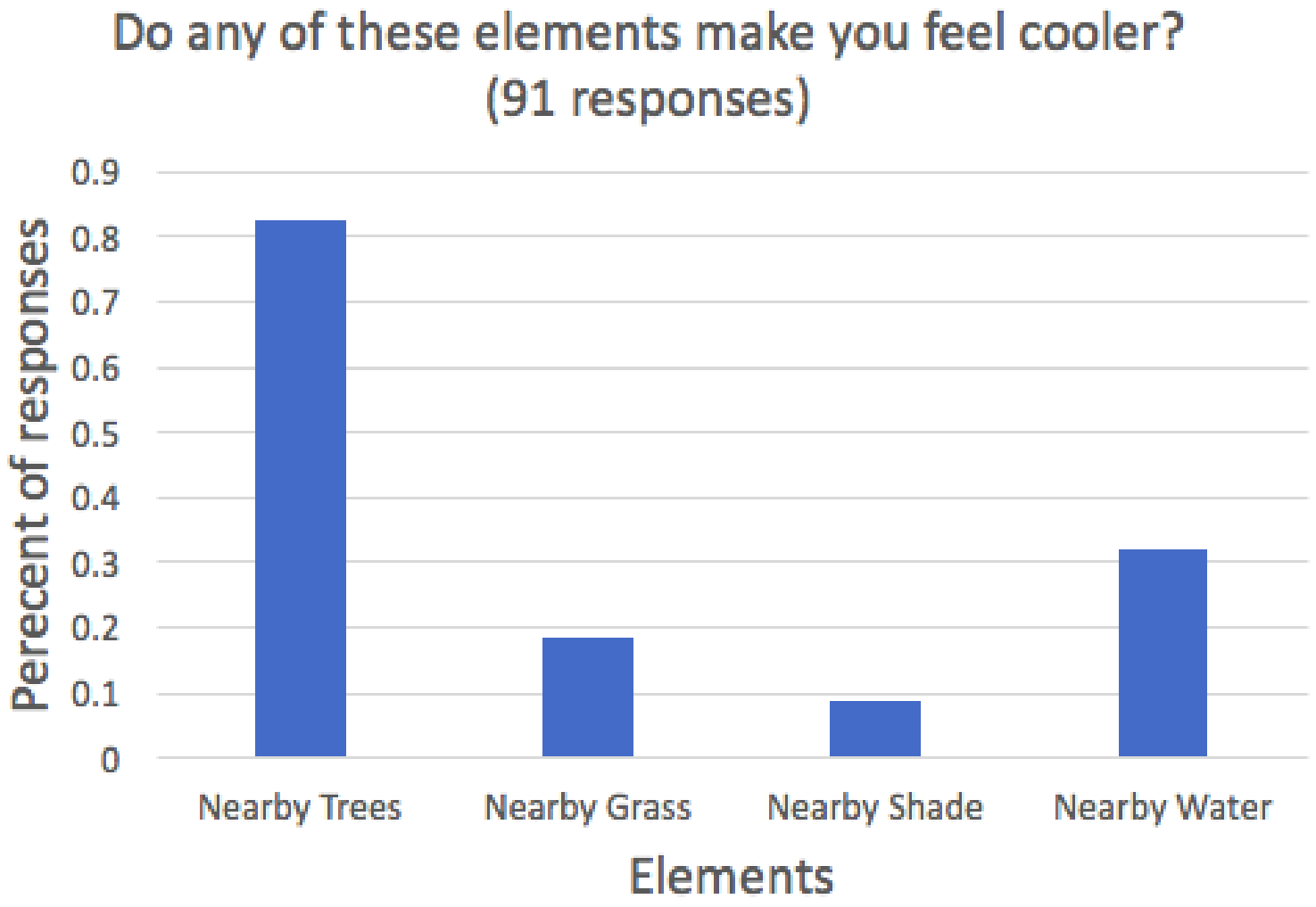
9. What is your age?

- ☐ 18 – 24
- ☐ 25 - 34
- ☐ 35 - 44
- ☐ 45 - 54
- ☐ 55 - 64
- ☐ 65 or older

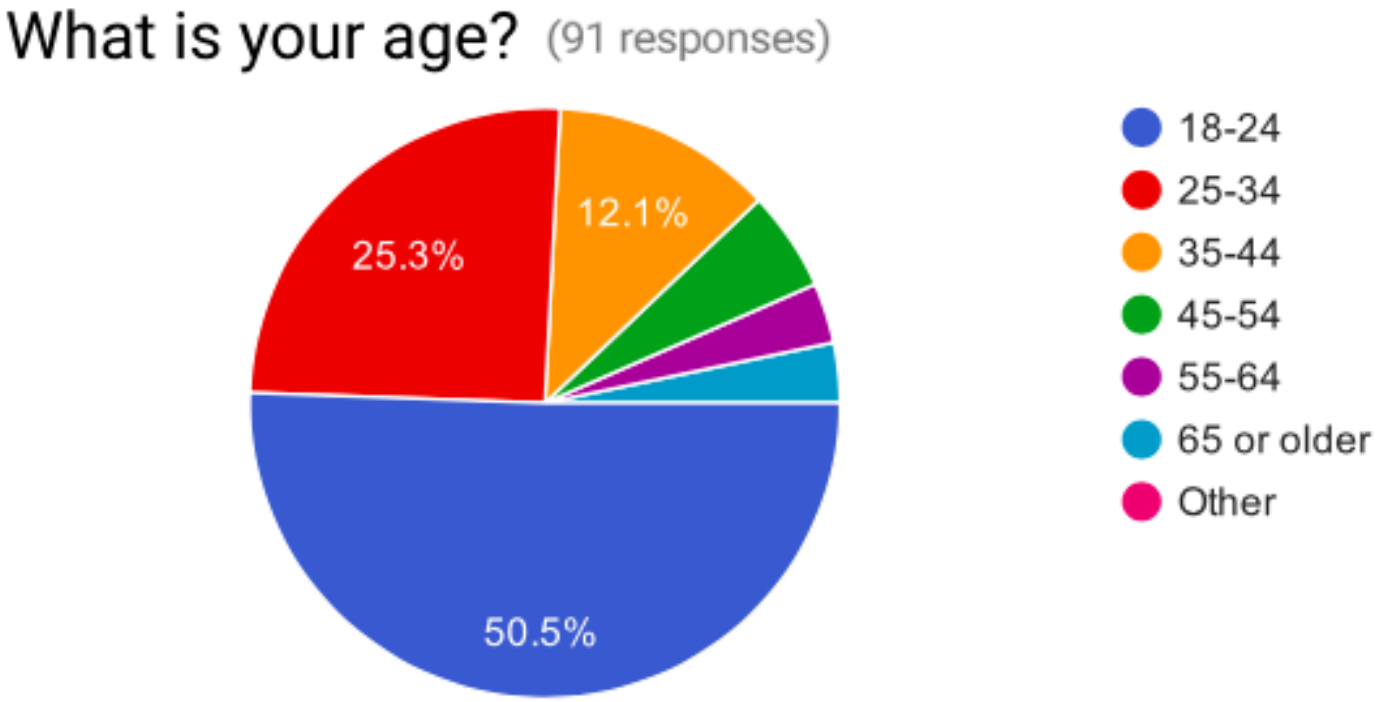
10. What is your household income?

- ☐ 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

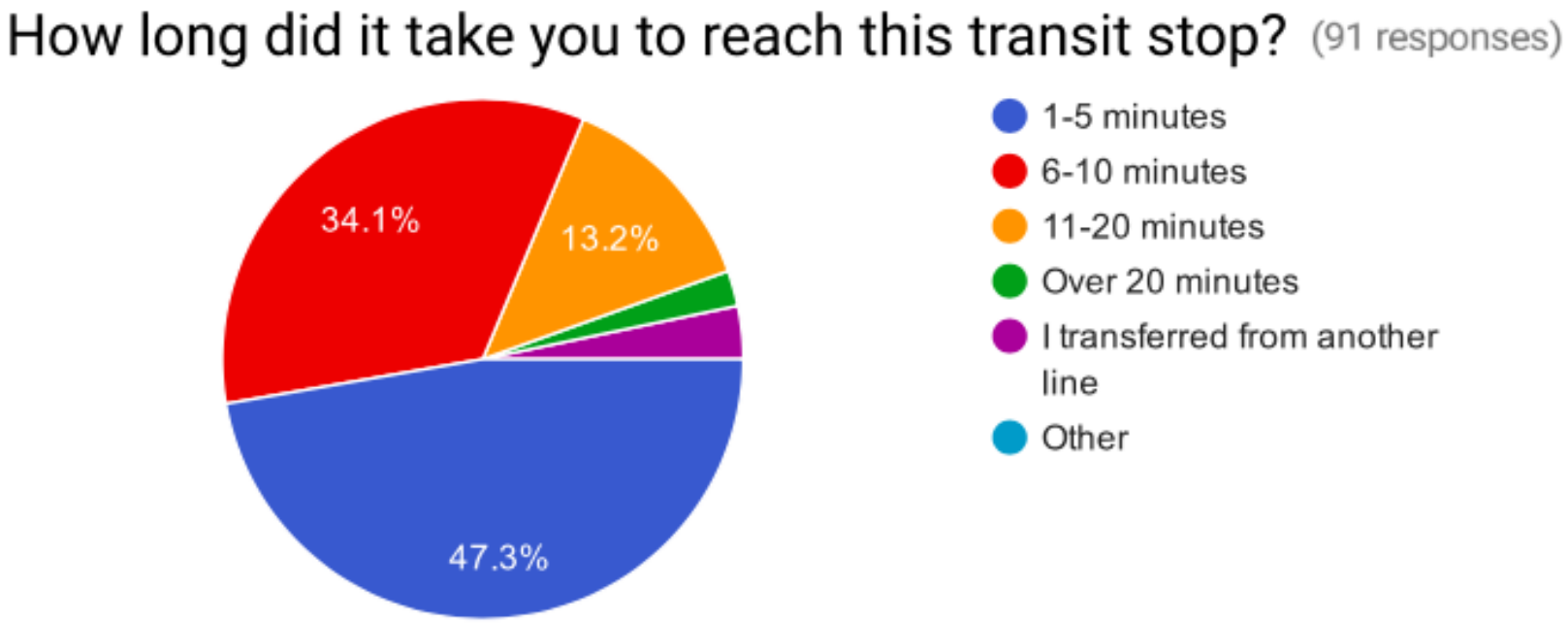
Travel Survey Results



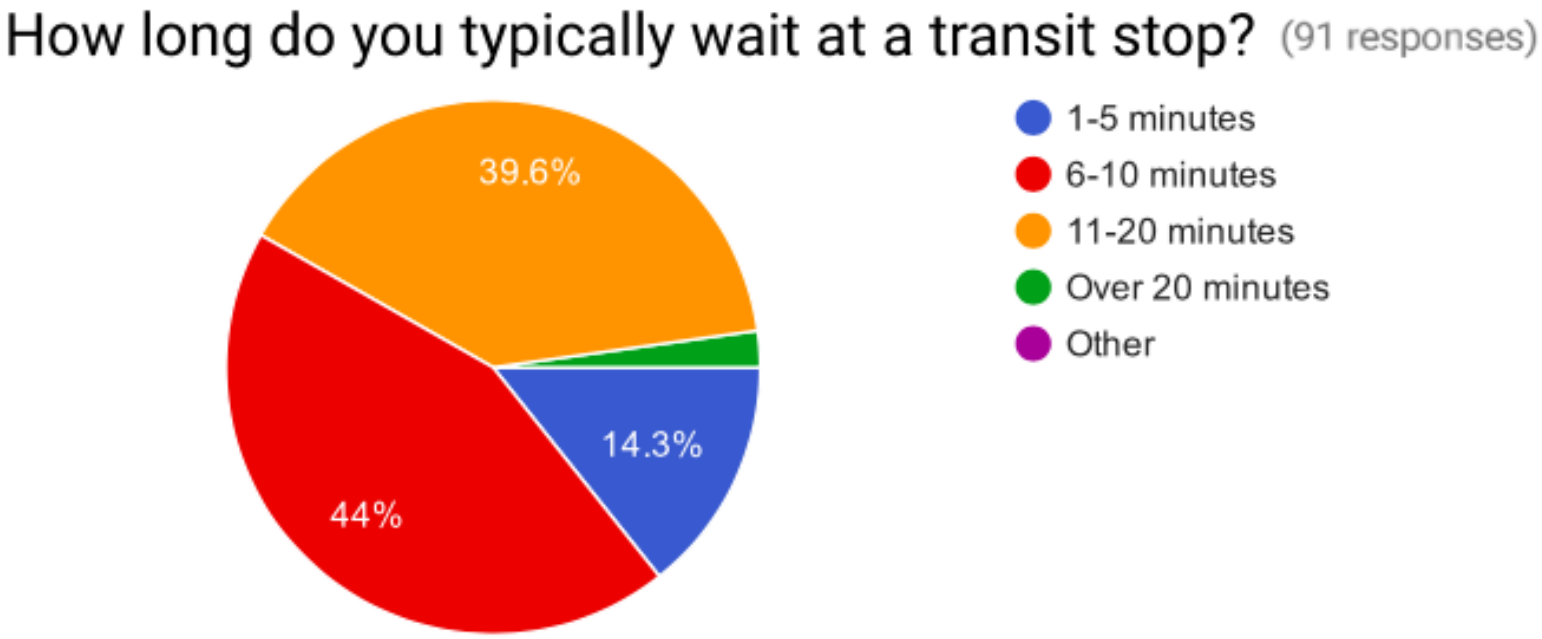
Travel Survey Results



Travel Survey Results



Travel Survey Results

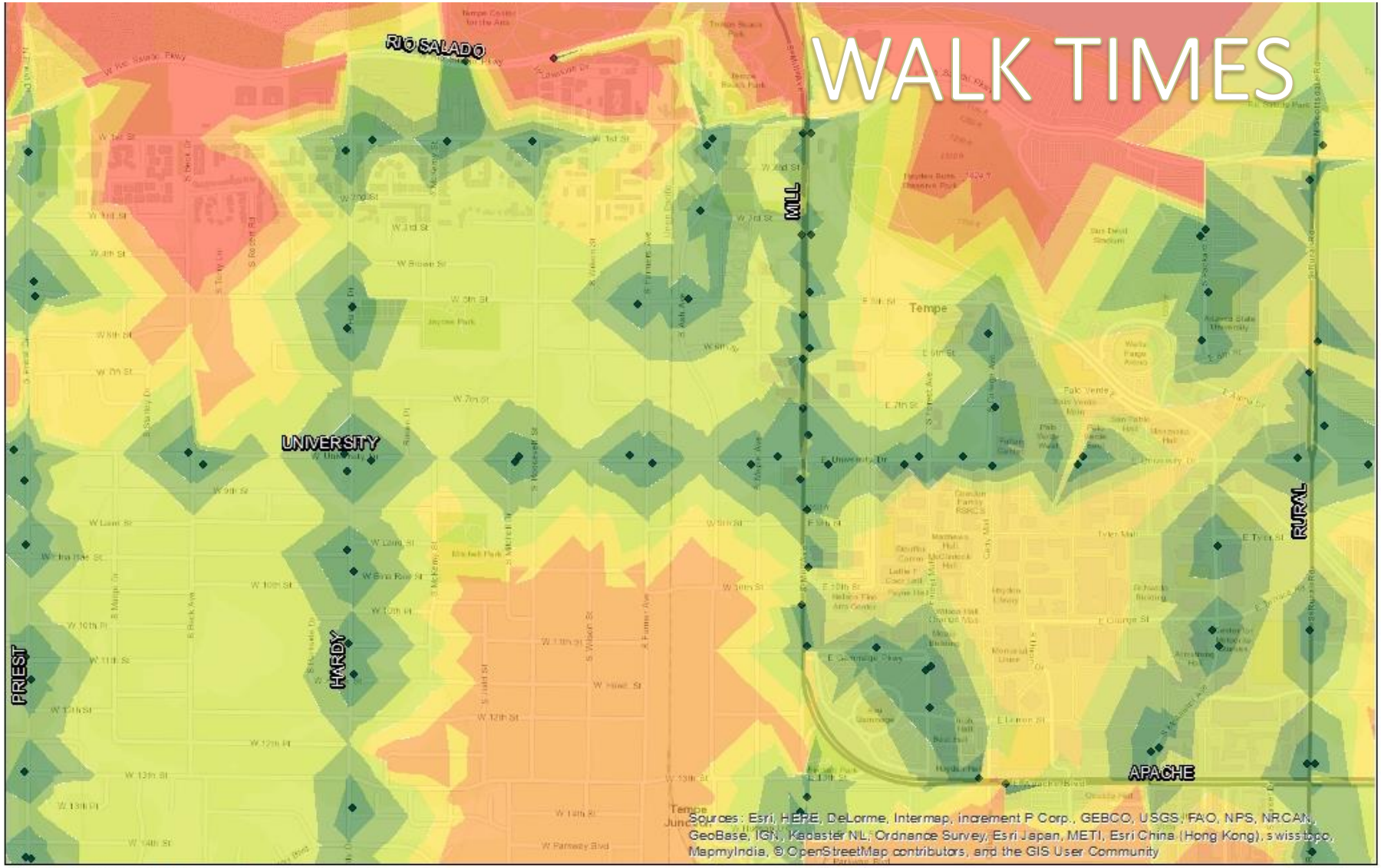


Transit Behavior

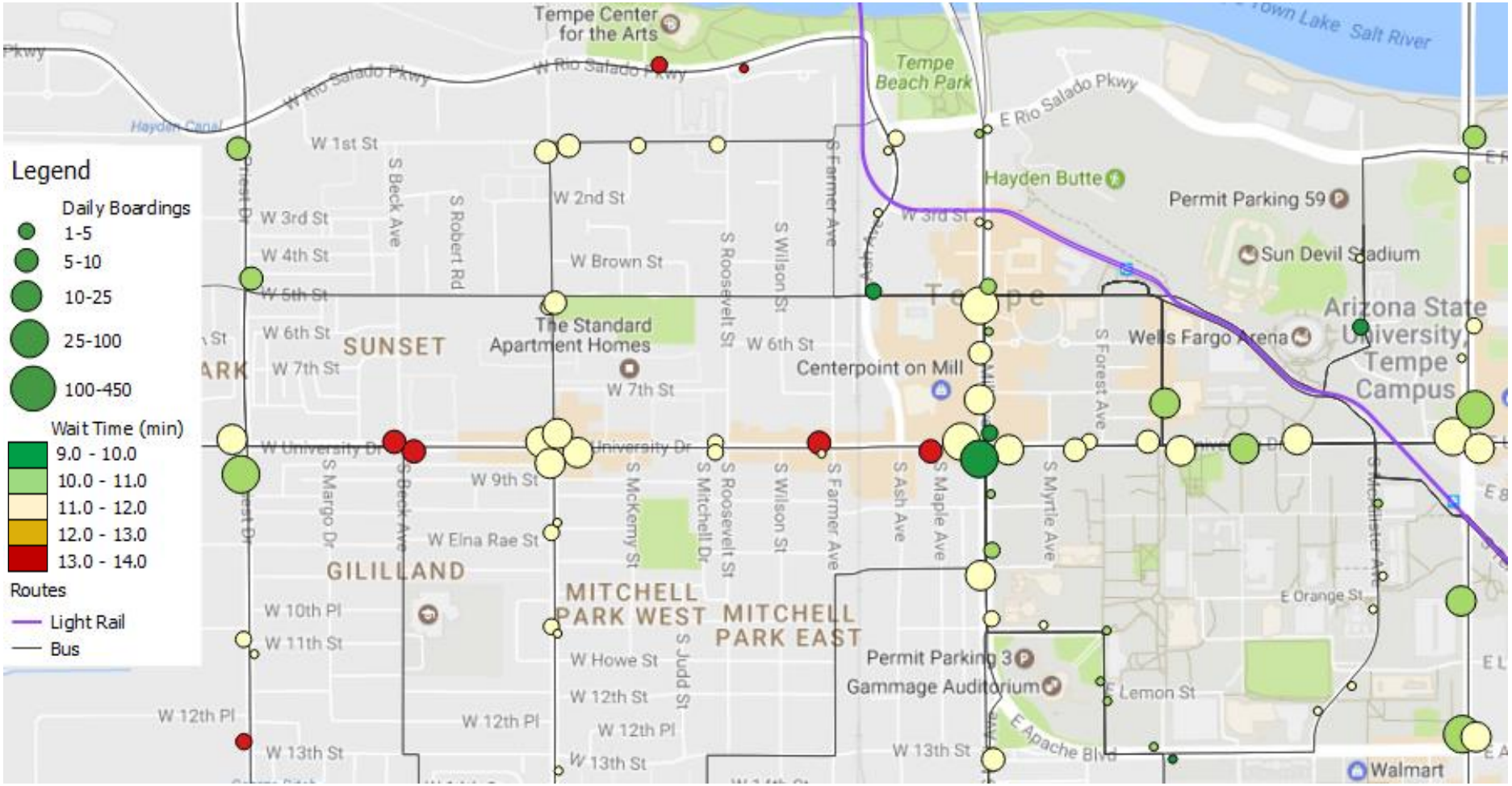
Survey Walk + Wait Time Results

		Walk Time			
		1-5 minutes	6-10 minutes	11-20 minutes	Over 20 minutes
Wait Time	1-5 minutes	7	3	3	-
	6-10 minutes	23	8	6	1
	11-20 minutes	13	17	3	-
	Over 20 minutes	-	2	-	-

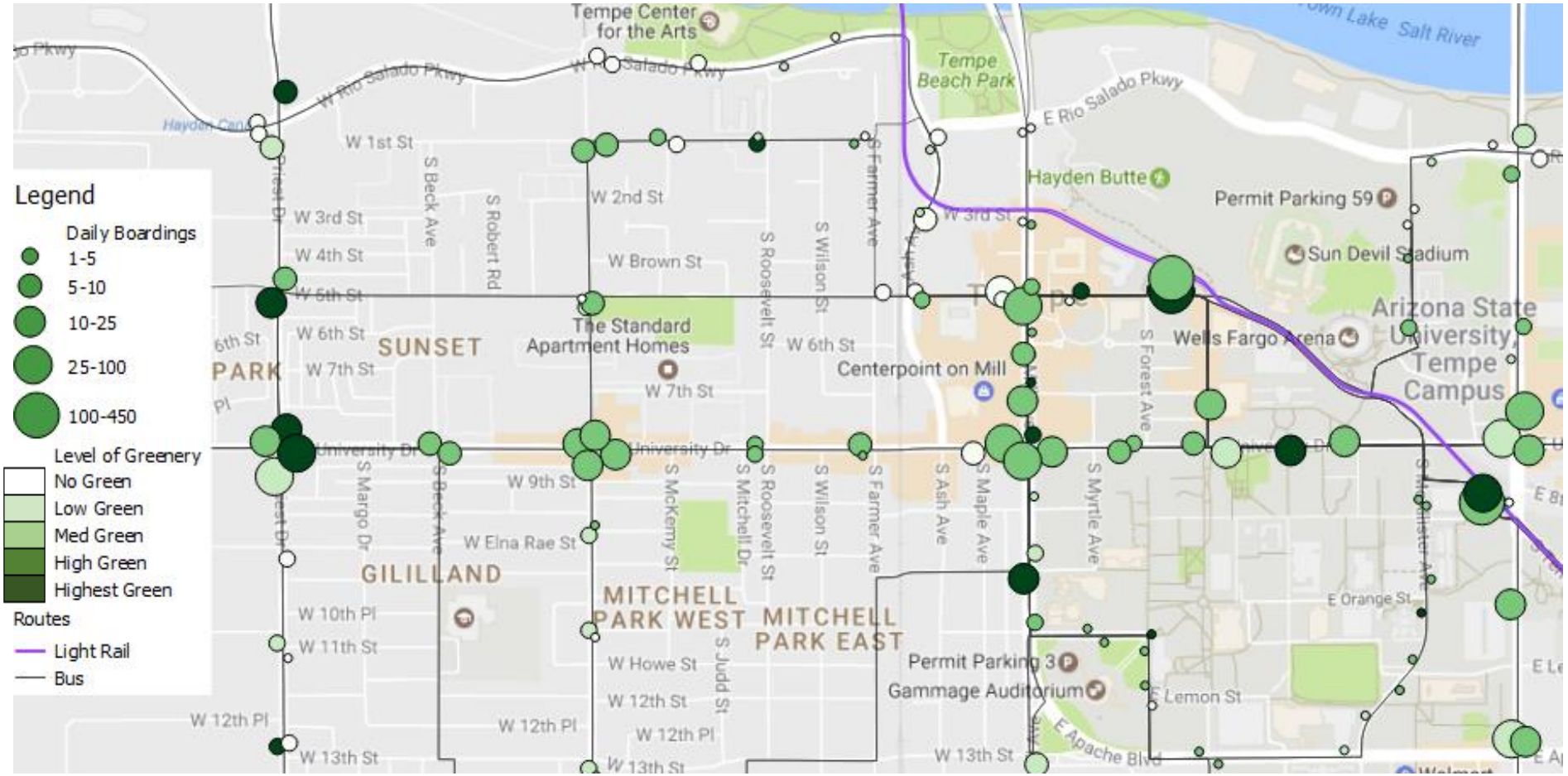
WALK TIMES


RIO SALADO
MILL
UNIVERSITY
HARDY
PRIEST
RURAL
APACHE
Tempe
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Minutes Walked
0-1
1-2
2-3
3-4
4-5
5+
Transit Stops
0 0.075 0.15 0.3 0.45 0.6
Miles
N

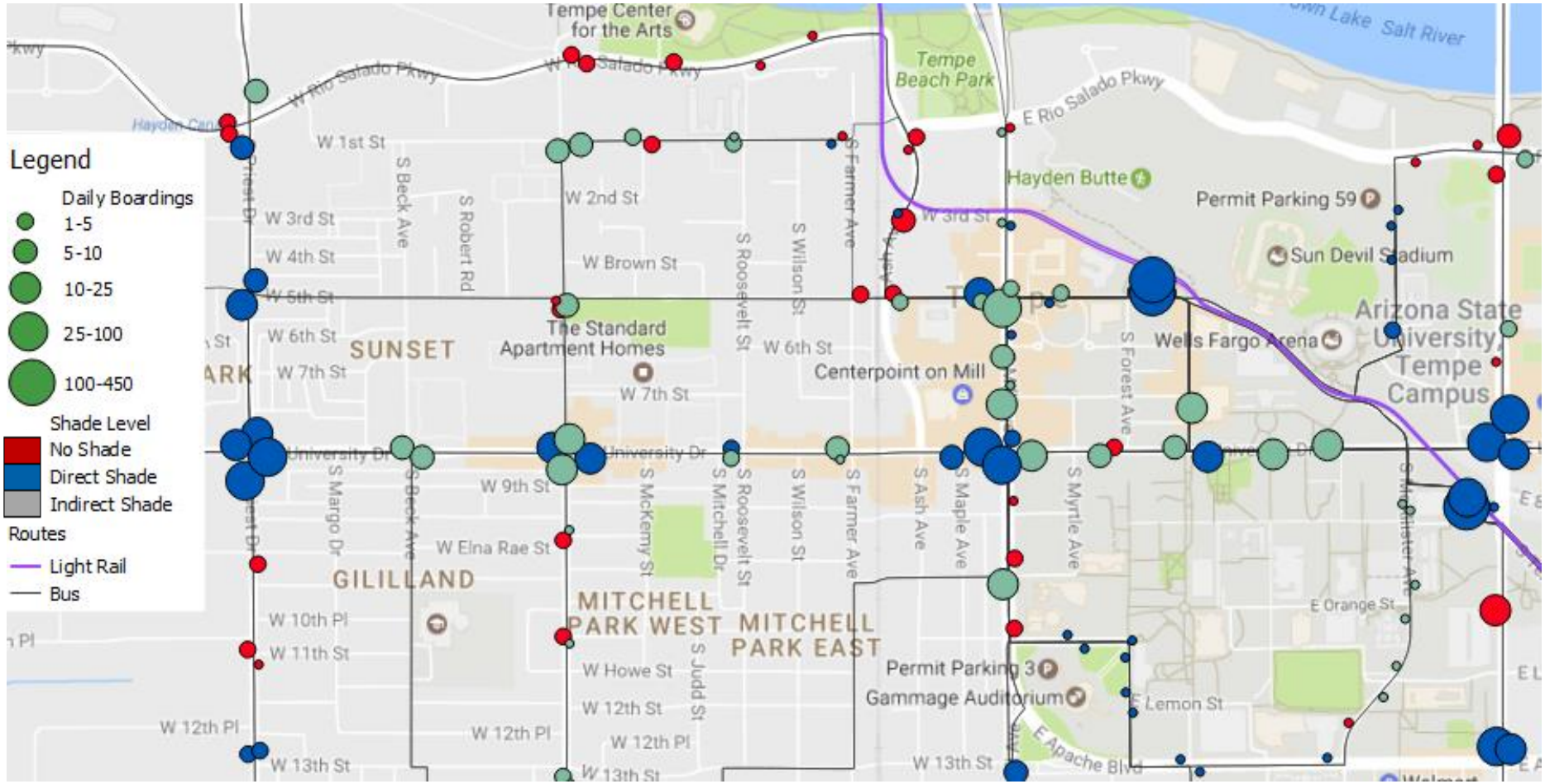
Wait times + Ridership



Greenery + Ridership

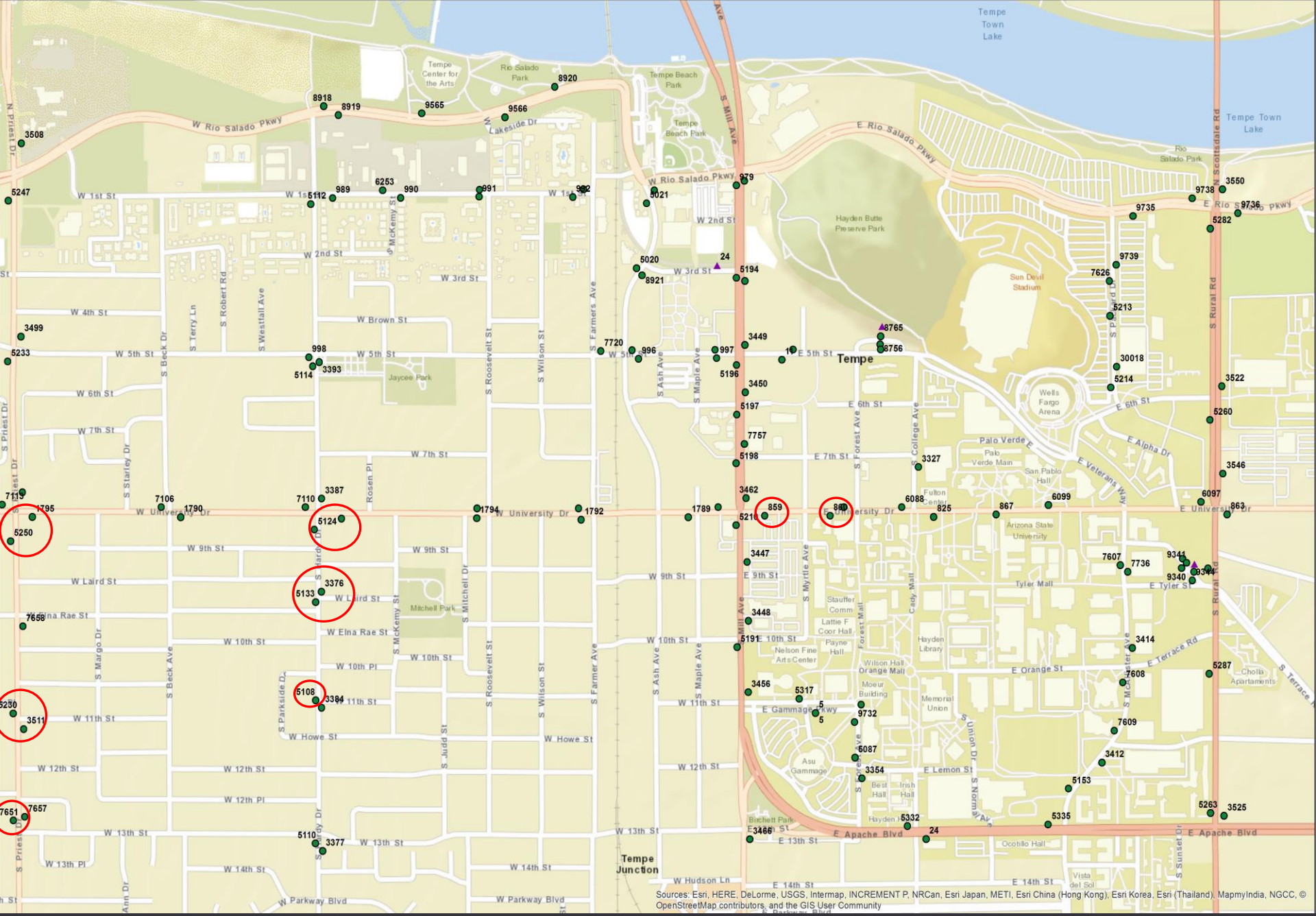


Shade Level + Ridership



What stops/routes to focus on?

Exposure



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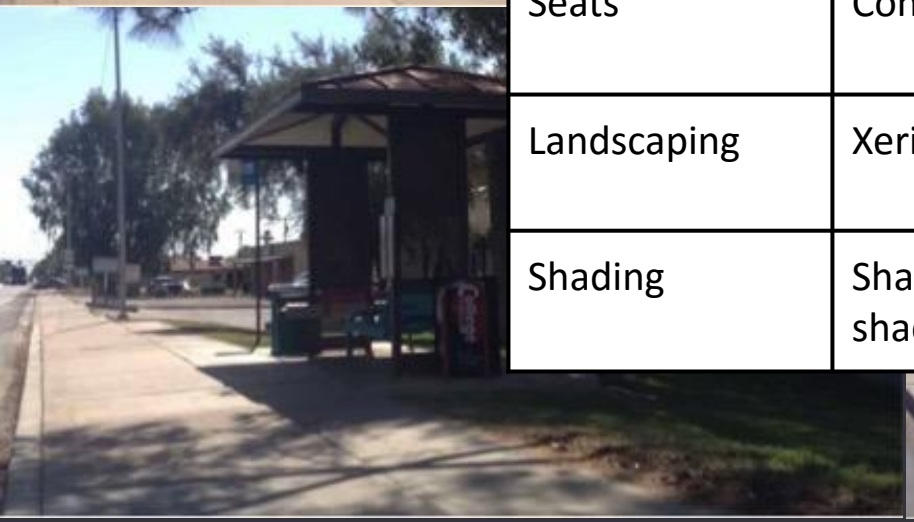
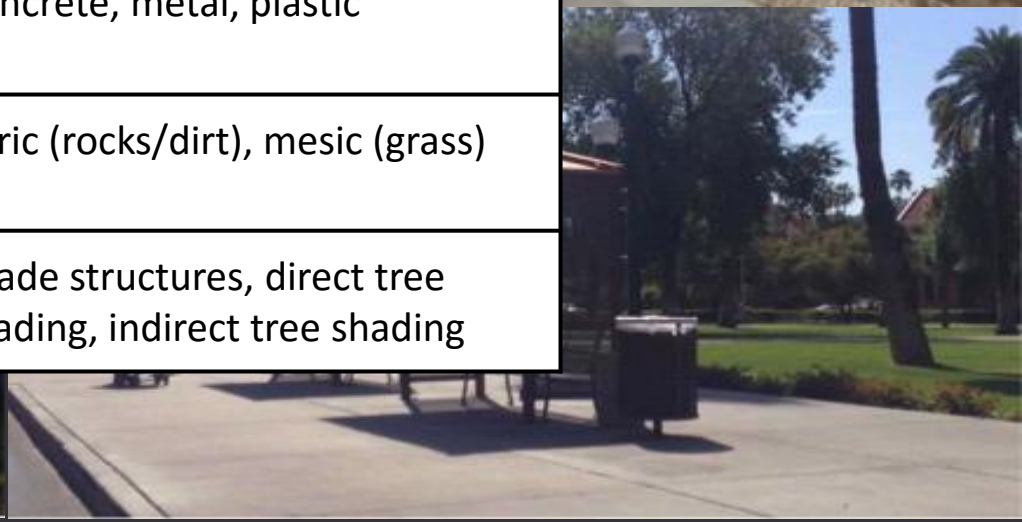
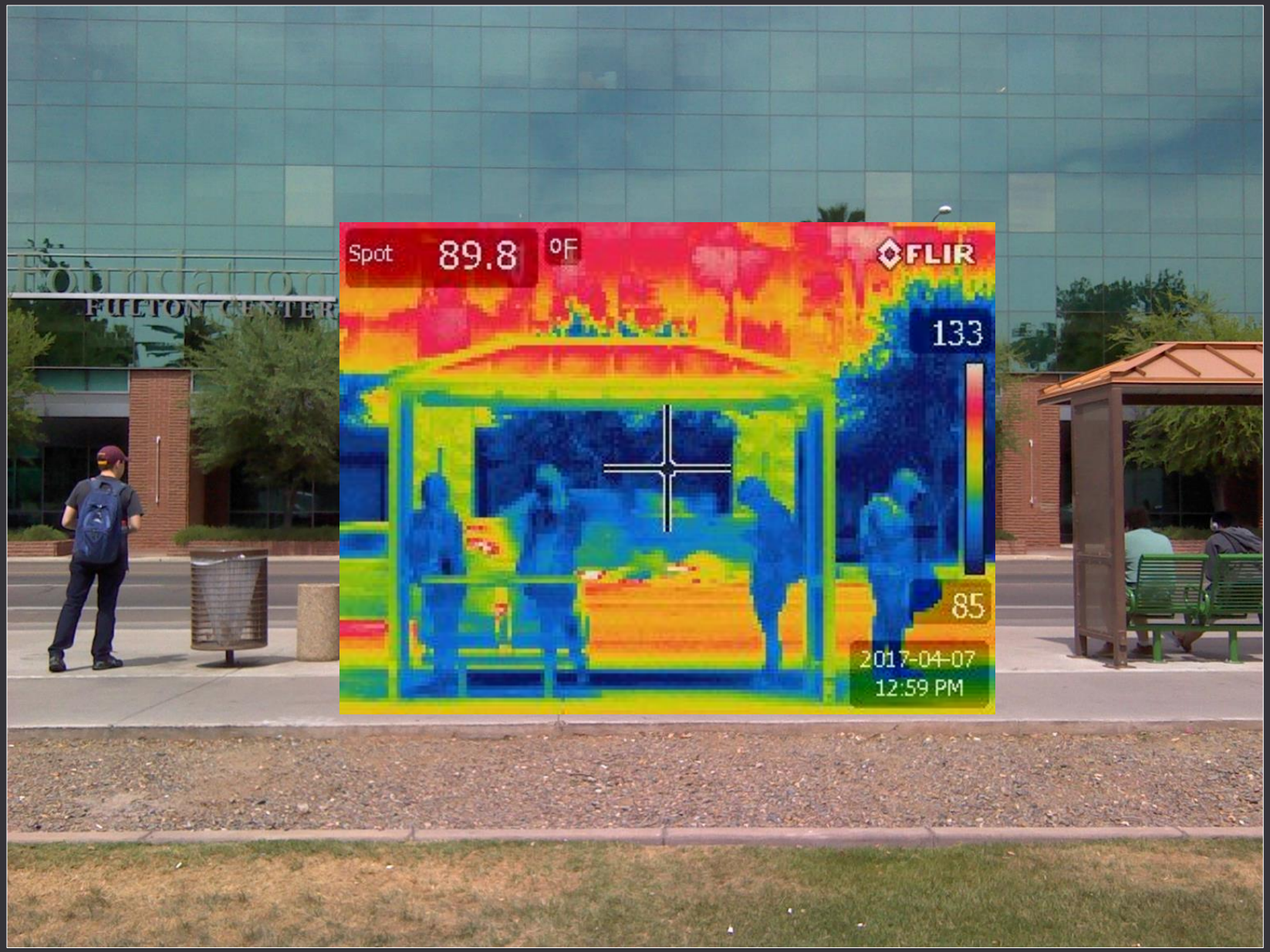
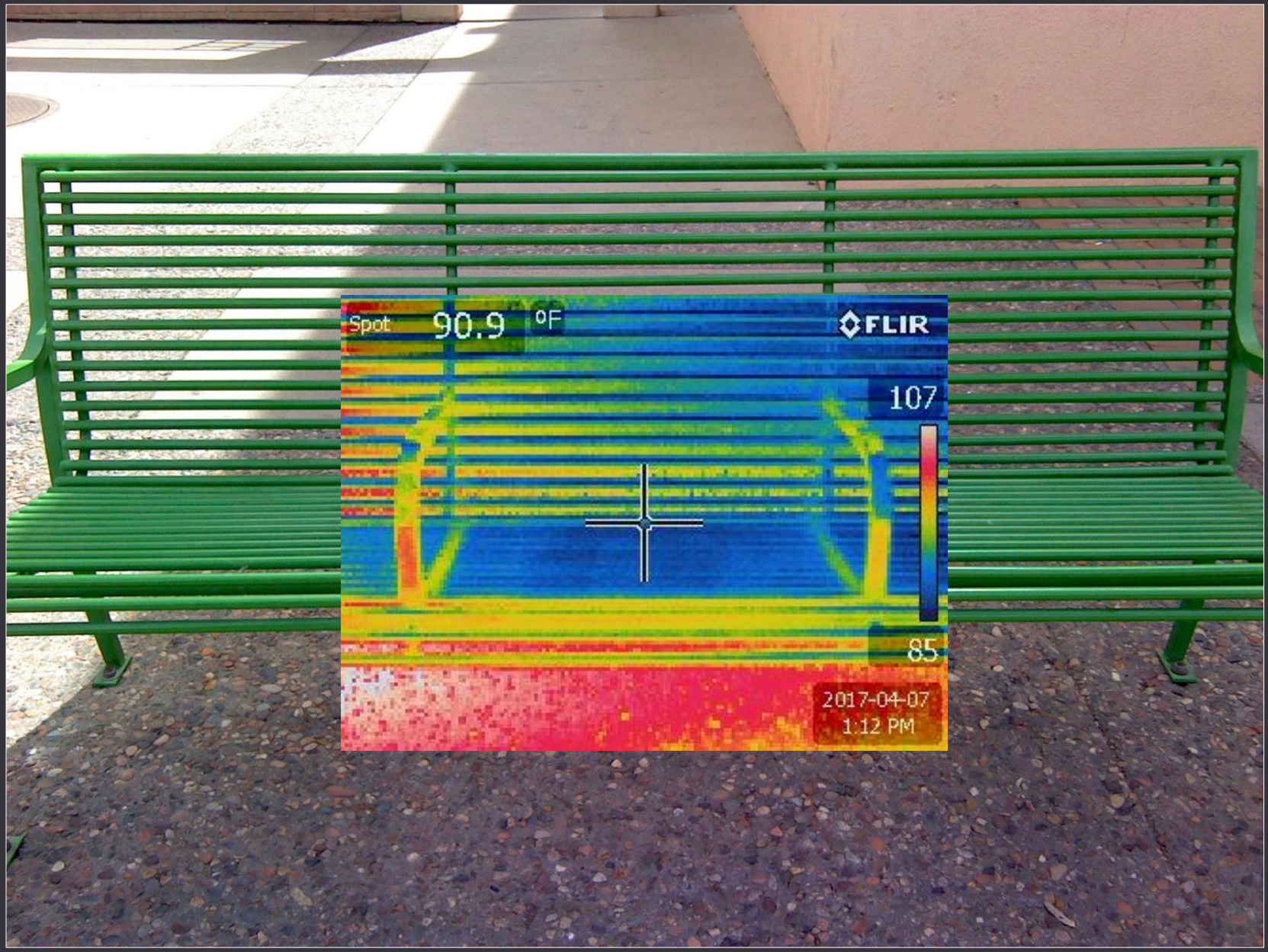
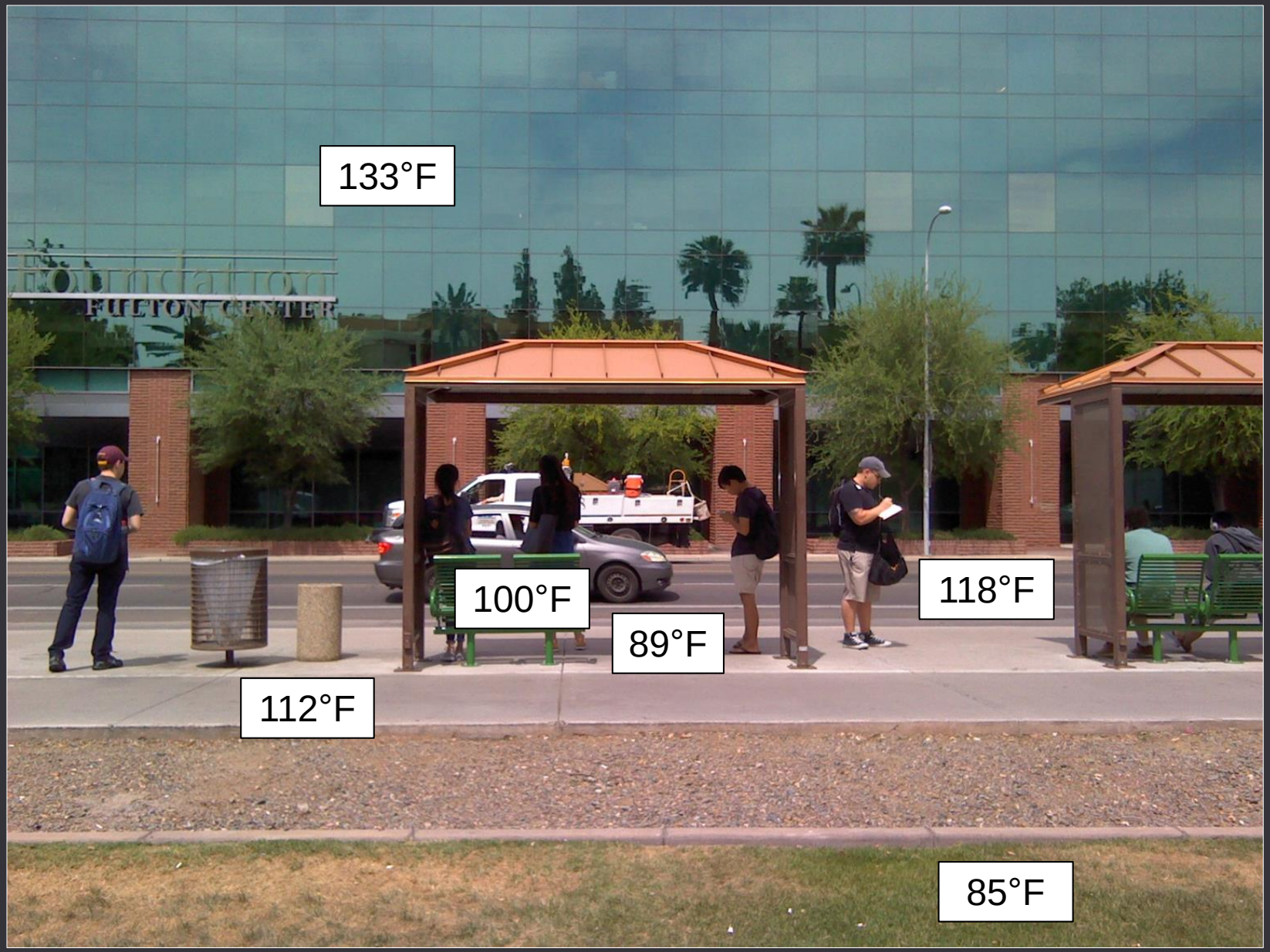



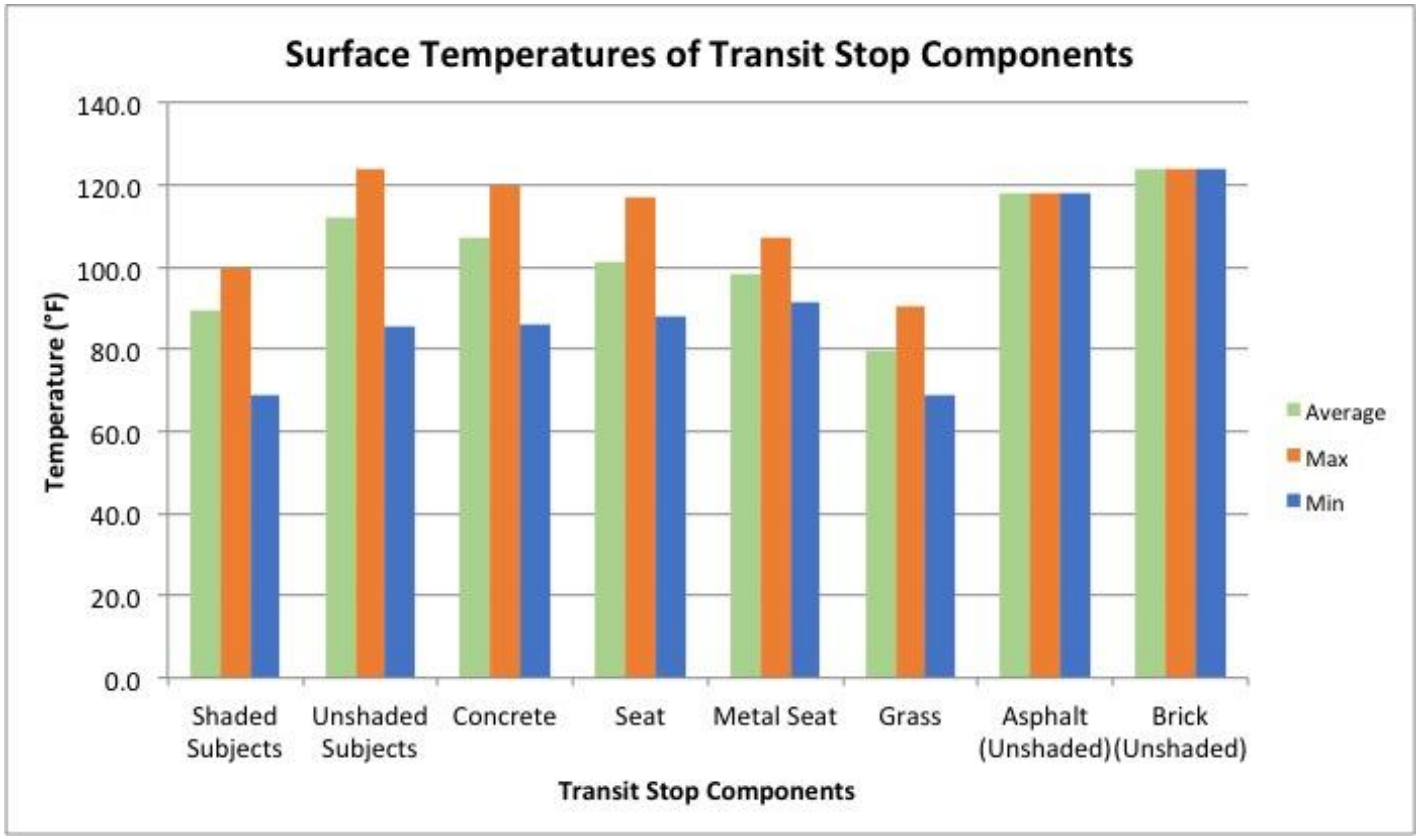
Stop component	Classification
Pavement	Concrete, brick, asphalt
Seats	Concrete, metal, plastic
Landscaping	Xeric (rocks/dirt), mesic (grass)
Shading	Shade structures, direct tree shading, indirect tree shading


Spot 89.8 °F
FLIR
133
85
2017-04-07
12:59 PM


Spot 90.9 °F
FLIR
107
85
2017-04-07
1:12 PM

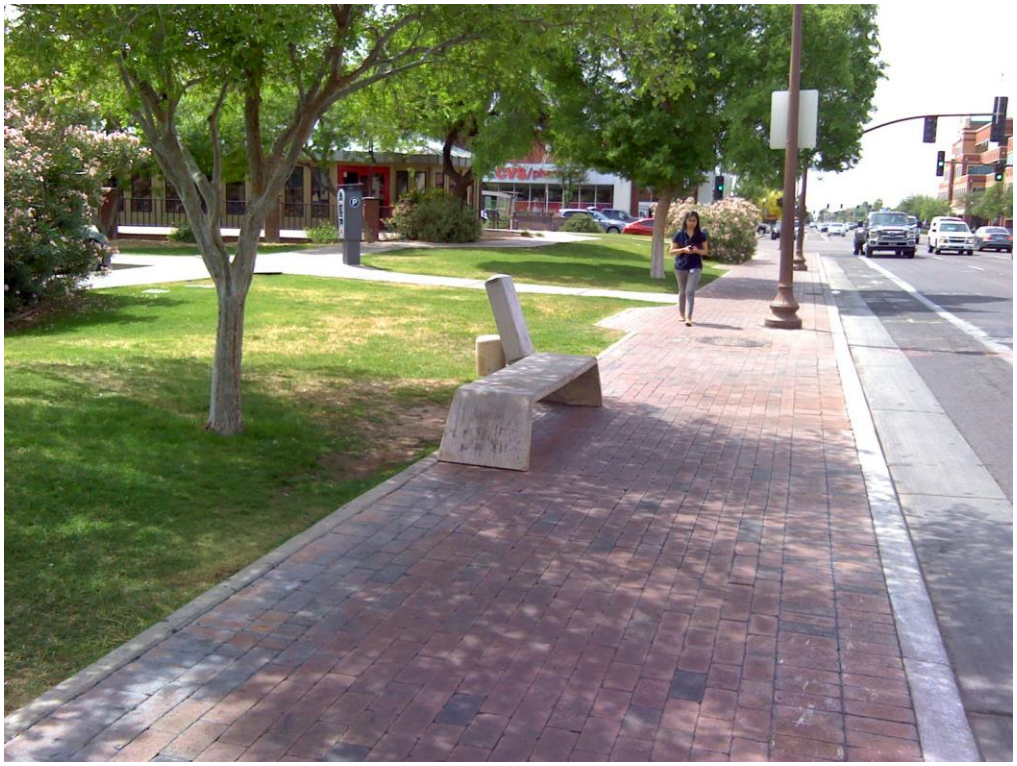

133°F
FULTON CENTER
100°F
89°F
118°F
112°F
85°F

Results: Impacts of shade type on surface temperatures



Sampling time: March & April 2017
Largest temperature difference: 69.1 °F – 124 °F

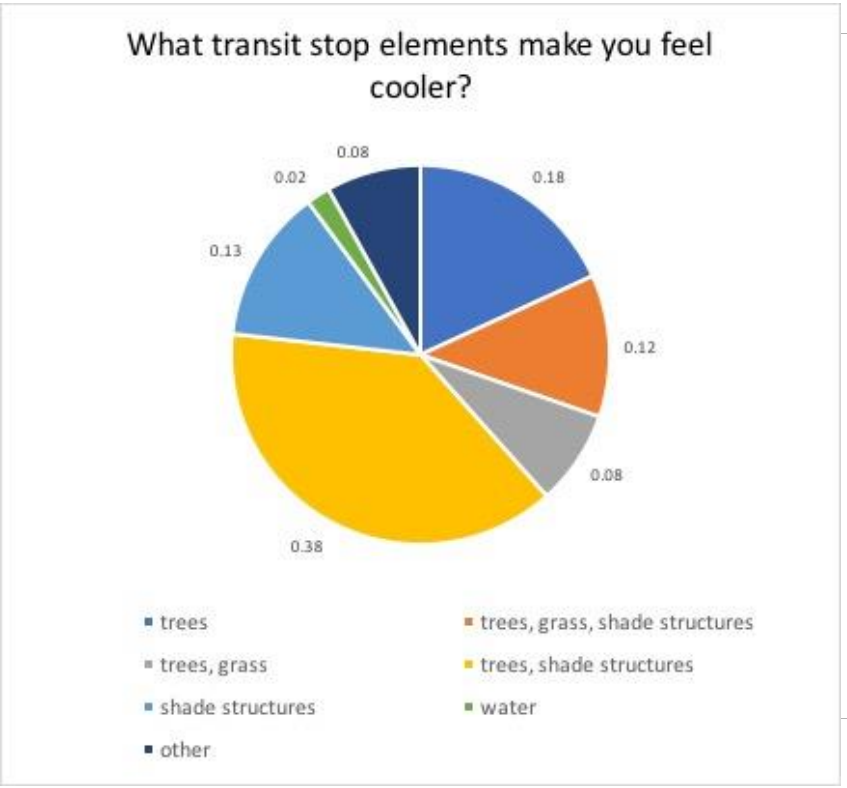
Results: Impacts of shade type on thermal characteristics

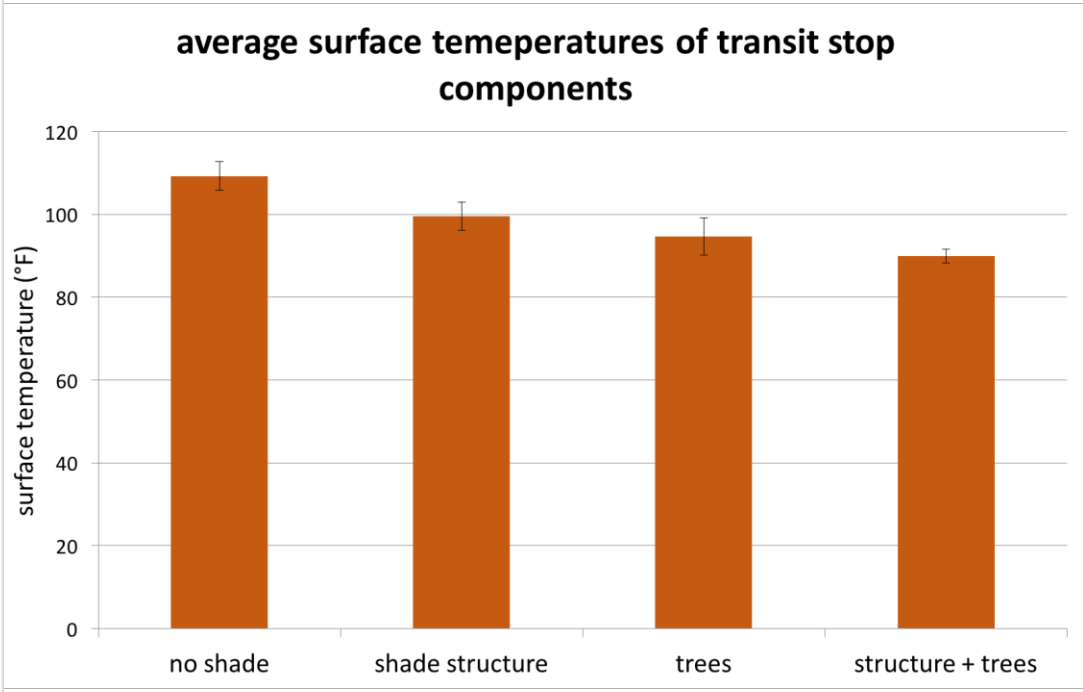


Shade type is the dominant control for surface and air temperatures at transit stops

- $R^2 = 0.69$
- Significant relationship to surface temperature ($p<.001$)
- Inconclusive relationship to air temperature

Results: Heat perceptions versus actual field data

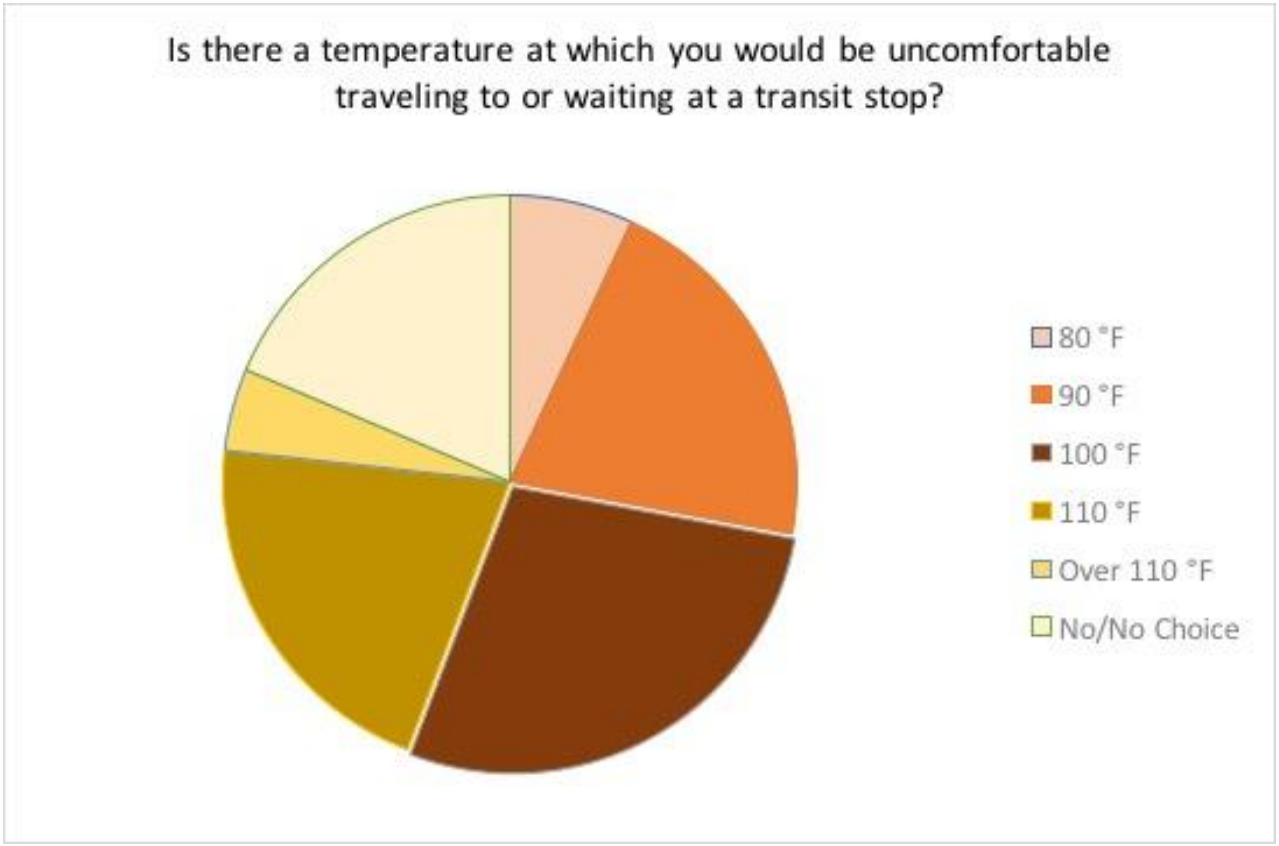




77% of survey respondents perceived that trees provided significant heat relief

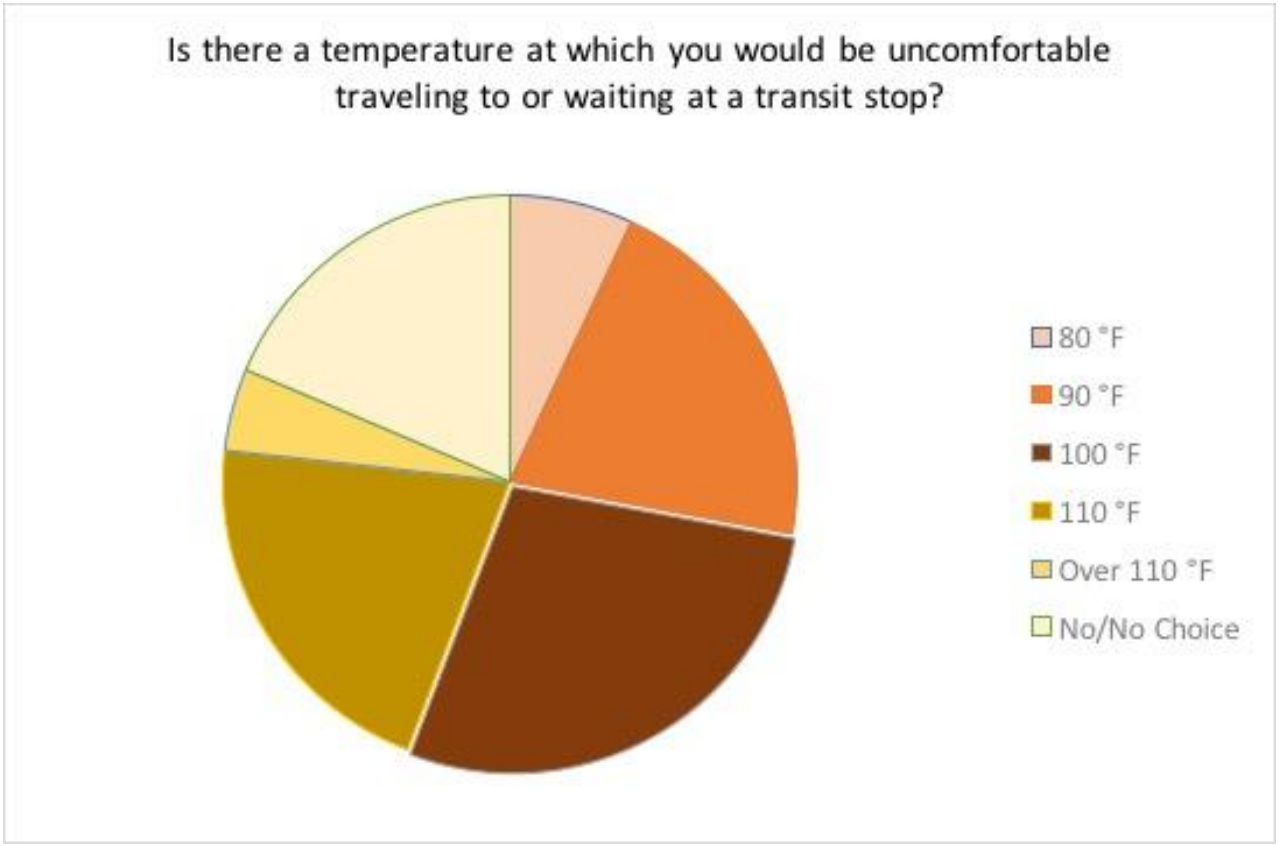
Field measurements indicated tree shading provided on average greater heat mitigation versus built shade structures

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

Survey Walk + Wait Time Results

Wait Time \ Walk Time	1-5 minutes	6-10 minutes	11-20 minutes	Over 20 minutes
1-5 minutes	7	3	3	-
6-10 minutes	23	8	6	1
11-20 minutes	13	17	3	-
Over 20 minutes	-	2	-	-

+

Results: Impacts of shade type on surface temperatures

Subject Catagory	Average	Max	Min
Shaded Subjects	89.441176	99.9	69.1
Unshaded Subjects	111.98333	124	85.7
Concrete	107.11667	120	86.2
Concrete (Shaded)	91.85	98.1	86.2
Concrete (Unshaded)	114.75	120	109
Seat	101.4	117	88.3
Seat (Shaded)	92.3	95.7	88.3
Seat (Unshaded)	110.5	117	100
Metal Seat	98.625	107	91.6
Metal Seat (Shaded)	95.833333	99.9	91.6
Metal Seat (Unshaded)	107	107	107
Grass	79.5	90.3	69.1
Grass (Shaded)	77.95	90.3	69.1
Grass (Unshaded)	85.7	85.7	85.7
Asphalt (Unshaded)	118	118	118
Brick (Unshaded)	124	124	124

In need of a common denominator → Convert to 4 level Likert Scale

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 of 4

Wait Time	Walk Time			
	1-5 Minutes	6-10 Minutes	11-20 Minutes	Over 20 Minutes
1-5 Minutes	1	2	3	4
6-10 Minutes	2	4	5	6
11-20 Minutes	3	5	6	7
Over 20 Minutes	4	6	7	8

Results: Impact of Shade Type on Surface Temperatures		
Temperature of Transit Stop Infrastructure Elements by Shade Level	Avg. Surface Temp.	NOAA Heat Index Numerical Value
Concrete (Shaded)	91.8	1
Concrete (Unshaded)	114.75	3
Seat (Shaded)	92.3	2
Seat (Unshaded)	110.5	3
Grass (Shaded)	77.95	0
Grass (Unshaded)	85.7	1
Metal Seat (Shaded)	95.833	2
Metal Seat (Unshaded)	107	3
Asphalt (Unshaded)	118	3
Brick (Unshaded)	124	3

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

Category	Infrastructure Name	Unit Cost
Urban Cover	Grass	Material: 0.05¢/ft^2 & Labor: $30/hr
	Shrub	Material: $10~16.65/gallon Planting: $106~2423/tree
	Tree	Material: $7.58~28/gallon Planting: $106~2423/tree
Urban Fabric	Cool Pavement	$2 - 2.50/$ft^2$
	Green Pavement	$1.5 - 5.74/ft2
	Green Wall	$90 - 135/$ft^2$
Urban Metabolism	Green Roof	$10/$ft^2$
	Solar Panel	$2.87-3.85 per watt Labor: $0.44 per watt
	Water Fountain	Material: $60~1800/each Labor cost: $320~520/each installation Excavation: $0.047~2.28/sqrt

- 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


ASU
Arizona State University
Questions?
urbansustainability.lab.asu.edu