Urban Infrastructure Anatomy and Sustainable Development

CEE598: Civil, Environmental, & Sustainable Engineering
PUP598: Geography and Urban Planning
SOS598: School of Sustainability

CON252: Construction Methods, Materials, and Equipment
Population Growth

Maricopa County Population

0 1,000,000 2,000,000 3,000,000 4,000,000 5,000,000 6,000,000 7,000,000 8,000,000 9,000,000
Cumulative Heat Vulnerability Index and Heat-Related Deaths (2000-2008) in Census Block Groups in Eastern Phoenix Metropolitan Area

Source: S Harlan, J Declet-Barreto, W Stefanov, and Diana Petitti, 2013, Neighborhood Effects on Heat Deaths: Social and Environmental Predictors of Vulnerability in Maricopa County, Arizona, Environmental Health Perspectives, 121(2).
Maricopa County Heat-Associated Deaths

Hurricane Sandy: 273 deaths

Extreme heat events are associated with increased morbidity and mortality.
Under climate change, extreme heat events are expected to become more frequent, more severe, and longer-lasting.

**MARICOPA** - RCP 2.6: 340—415% increase; RCP 4.5: 380-510% increase; RCP 8.5: 1200-1800% increase.

TRANSPORTATION

• Key Amenities

NEIGHBORHOODS

• Land Uses

• Transition Projects

BUILDINGS

URBAN INFRASTRUCTURE ANATOMY

• Materials Pallet

• Vegetative Shading

• Structural Shading

CONSTRUCTION MATERIALS & METHODS (CON 252)
Will develop cost estimations of infrastructure changes

ENVIRONMENT

SOCIAL

Project Overview
Neighborhoods & Buildings

Core Values - Assets within the City of Mesa
Neighborhoods & Buildings

Key transitions that can enable a Sustainable Community
Neighborhoods & Buildings

Overview

• Key Existing **Neighborhood Components** prime for improvement

• General Land **Areas** that could improve the local **built environment**

• Specific **Spaces** that can serve to **enhance the community**

• Unique **transformational** development projects that contribute towards SOS

• Aspects of **building composition** that relate to the **Health** of communities
Neighborhoods & Buildings

Goals

• Promote Community Development Projects that reinforce local values
• Improve the local Environment through Heat mitigation strategies
• Encourage Rethinking of the Right of Way to reduce heat and increase safety
• Discuss alternative building compositions that could enhance quality of life
• Recommendations for addressing health of communities through materials
Key components that can be leveraged to reduce heat exposure
Opportunities within our project scope represent just a fraction of the cities areas to encourage investment in:

- mixed use buildings
- consolidate parking
- providing shade
- cleaner energy production
- cooling refuge areas
- enhanced amenities
- safety and security
- new building forms
- proper material pallets

Urban Community Enhancements
Neighborhoods & Buildings

Neighborhood Transformations

- Major New Developments
- Civic Enhancements
- Prime Adaptive Parcels
- Prime Adaptive Blocks
- Existing Public Transit
- Micro Climate Corridor
- Pedestrian Precession
- Traffic Calming Modes
- Exhaust Canopy’s
Unique Development Projects w/n project boundaries

- **NWC of project area** for adaptive commercial use
- Mesa Center multifunctional canopy's (shade energy shelter)
- Main street revitalization and adaptive land uses
- Intersection prototypes for exhausting emissions and heat that create areas of refuge for the public
- Hibbert (NS) New developments and street design (shade vege h20 access)
- 1st street (EW) traffic calming and multi-modal paths
Neighborhoods & Buildings

Prototype for Mixed-Use Commercial Spaces

Location - NWC of project area | SEC of university and center

Reality that parking is a powerful force in our auto dominated region of Maricopa county

Alternative response for a prime parcel could be a building typology that responds to local needs

Flexibility of retail spaces and commercial offices while supporting vehicle related functions such as food trucks pop up markets and even overflow parking
Neighborhoods & Buildings

Giles Spaces - Mixed-Use Community Areas

Location – Mesa Convention Center

- Approx. size 3.6 acres
- Est. cost 5.5 million
- Municipally owned property
- ROI Est. at 17 years

Opportunity to provide areas of refuge through public open space that could showcase amenities under solar shading
Neighborhoods & Buildings

Example New Developments along Main street
Neighborhoods & Buildings

Example Prototypes for Street Level Enhancements
Material strategies for reducing heat

Using light colors and alternative envelopes such as louvers we can reduce the heat being absorbed and radiated at a meso-scale.
Representation of heat lost through building components

- Approximately 40% of air loss/gain originates from the envelope.

Source: US Home Builders Association and US Department of Energy
Tony Woods Air-tight buildings, 2005; Richard S. Duncan, Phd, PE
The Role of Air Sealing
"As the green design field matures, it becomes ever more clear that integration is the key to achieving energy and environmental goals especially if cost is a major driver."

Building Green Inc. (1999)

## Alternative Material Recommendations

### EXISTING/ CONVENTIONAL

1. Bricks Walls $40/sq. ft.
2. Concrete - Based of Portland Cement
3. Paint
4. Wood products
5. Lighting
6. Windows regular glazing
7. Glazing $12 per sq. ft.
8. Roof-absorbance 0.7
9. HVAC coupled with min req’d insulation
10. Flooring - Regular Carpets
11. Energy codes – IECC

### UPGRADE/ SUSTAINABLE

1. CMU with Brick veneer $23 per sq. ft.
2. Fly ash/Slag based concrete - More Durable and slightly less expensive by 0.5-1$ per ton
3. Low-emitting & Recycled paint can cost $3 less/gallon
4. Certified Wood door costs is $150 less expensive
5. Solar tubes and LED lighting
6. Optimized wall to window ratio, U-factor 0.31 & Shading Coefficient of 0.39
7. Spandrel glass $18 per sq. ft.
8. Cool/White Roofs - Absorbance of 0.3
9. Highly efficient Active system Integrated with Passive cooling (Solar chimney, Cooling towers & fans)
10. Carpets with recycled contents costs $15 per yard less than traditional carpet
11. ASHRAE has higher efficiency (10% higher R-Value)
Building Diagram for Sustainable Elements

- **Efficient Insulation**
- **Windows with a Good U Value**
- **Excess Heat from the Indoor Air Are Used to Heat the Incoming Air and Tap Water**
- **One Radiator on Each Floor Can Heat the Whole House**
- **Grey Water Heat Recovery, Drain Water Heat Recovery**
- **Radiant Floor Heating Heats the House**
- **The Boiler Gets Heated Water from the Solar Collectors, an Energy Well, the Air System and the Water Heat Recovery Systems**
- **Atrium - A Good Source of Daylight**
- **Solar Cells (Photovoltaic Panels) 150M2 - 19200Kw/h-year**
- **Solar Collectors 16M2 - 4000Kw/h-year**
- **Roof Slope 19 Degrees**
- **Thermal Mass Stabilizes the Temperature**
- **Light and Air Are Automatically Controlled Based on Use and Need**
- **Passive Exterior Sun Shading**
- **Rainwater Collection**

*img credit: Snøhetta architects*
Neighborhoods & Buildings

Material Cost Estimates & Guide

- Alternative sustainable materials are durable and less vulnerable to heat
- Most materials have lesser payback period. (Favorable cost-benefit analysis)
- Table below shows Energy Efficiency measured in a Building prototype showing energy cost reduction by 37% as compared to conventional design

<table>
<thead>
<tr>
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<th>Base-Case Building Annual Energy Cost</th>
<th>Sustainable Building Annual Energy Cost</th>
<th>Percent Reduction</th>
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<tbody>
<tr>
<td>Lighting</td>
<td>$6,100</td>
<td>$3,190</td>
<td>47.7</td>
</tr>
<tr>
<td>Cooling</td>
<td>$1,800</td>
<td>$1,310</td>
<td>27.1</td>
</tr>
<tr>
<td>Heating</td>
<td>$1,800</td>
<td>$1,280</td>
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</tr>
<tr>
<td>Other</td>
<td>$2,130</td>
<td>$1,700</td>
<td>20.1</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>$11,800</strong></td>
<td><strong>$7,490</strong></td>
<td><strong>36.7</strong></td>
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</tbody>
</table>

(Source: United States Department of Energy)
Transportation Group Overview

- Preliminary Design of Improved Corridors
- Increased Mobility for Pedestrians and Bicyclists
- Enhanced Transit Connectivity
- Protecting Pedestrians and Bicyclists from Heat Exposure
Transportation Group

Goals

• **Completion** of Mesa Light Rail Extension will increase pedestrian and bicycle traffic to Downtown Mesa

• Reconfigure significant corridors to *serve* this pedestrian and bicycle traffic

• Encourage further walking and biking with *upgraded* facilities

• Benefits businesses and *promotes* vibrant community
Transportation Group
Design Improvements

• Right Sizing First Street

• Rethinking Hibbert as Multimodal Corridor

• Bike Lanes on Center and Mesa Drive

• Connect Pepper to Mesa Drive

• Bicycle Marking Improvements
Transportation Group
Asphalt & UHI

• Soil, grass, vegetated, or xeriscaping areas can reduce release of solar radiant energy (heat flux) by 50-75%

• Vegetation near sidewalks reduces reflected heat and lowers temperature in pedestrian microclimate

• Together, these measures can lower ambient air temperatures by 5 to 15 degrees for pedestrians

* Takebayashi, 2012; Rosheidat, 2014; Santamouris, 2012
Transportation Group
Asphalt & UHI

Surface Temperatures by Type of Material

![Graph showing surface temperatures for different materials](image)

Conventional Asphalt  
Reflective Asphalt  
Xeriscaping

Source: Takebayashi, 2012
Transportation Group
Pedestrian & Bicyclist Mobility

Hibbert Road – Current Configuration
Mitigating Heat Vulnerability in Mesa, Arizona

Transportation Group

- Neighborhood circulator route
- Mobility without personal vehicle
- Also serves as mobile cooling environment
Transportation Group
Heat Vulnerability and Exposure

• Assessing Walking Routes and Exposure Limits

• OSHA: Outside activity less than 15 minutes in heat
• General population needs more protection, 5 minutes
• Corresponding walking distance at 3 ½ feet per second is roughly 1,000 feet.
• People walk in cardinal directions, radial equivalent is 750 feet.
• Analyze map for appropriate coverage and locating heat refuges.
• Final design distance to be determined in collaboration with public health officials
Transportation Group

Heat Vulnerability

- Locating Heat Shelters
- Consider Radial Travel Distances
Transportation Group Recommendations

- Reconfigure streets to promote walking and biking while reducing vulnerability to heat
- Increase the accessibility of the neighborhood by adding improved pedestrian access at Hibbert/University, First/Mesa, Pepper/Mesa
- Operate a neighborhood circulator bus route that connects the neighborhood to light rail while reducing walking/exposure durations
- Heat refuges to be placed at walking interval determined by coordination with public health officials
Landscaping, Shading, and Exterior Environments
Shading
Shading
Surfaces

Sidewalks: Rubbersidewalks™
- Maintenance requirements are significantly less in terms of life cycle costs than concrete.
- Rubber is 10 times less thermally conductive than concrete resulting in less heat release.

Benefits of rubber in pedestrian corridors (5.5 mi):

Labor Costs:
$8 per sq ft for Concrete => 2.11 million dollars
$1.5 per sq ft for Rubber => 396 thousand dollars

Using Fourier’s Law:
Thermal Conductivity of Concrete 1.5
Thermal Conductivity of Rubber 0.15

Absorbed heat for pedestrian corridor (5.5 miles):
Concrete: ~40,000 Watts/Kelvin
Rubber: ~4,000 Watts/Kelvin
Surfaces

**Parking Lots:** Consolidated parking structures or permeable surface lots.

- Convert to green space
Improvements to existing infrastructure

Expand existing incentives:

Xeriscaping – low water use vegetation
- 500 sq ft - 1,250+ sq ft
- $1000 - $3000

Reflective coatings

Green walls

Encouragement – permitting, mailings, event flyers, public classes, etc.
Stormwater Capture
Pedestrian Corridors & Heat Refuges

Pedestrian Corridor placement and implementation would be prioritized into 3 “Phases” with Heat Refuges positioned in strategic locations to support pedestrian travel.
Social and Institutional Considerations
Mitigation Plan

Goal: Reduce social vulnerability to heat in Mesa

Expand local incentives and programs
Seek external resources, funding, partnerships
Identify locations of vulnerability
Establish cooling centers & hydration stations
Internal and institutional support
Local Incentives and Programs

Green Building Programs
- Scottsdale and Chandler
- City, commercial, and residential buildings
- International Green Construction Code (IGCC) Heat Island Mitigation Worksheet
- Expedited priority plan review

Xeriscaping Incentives
- Glendale - up to $750 to convert 500 sq. ft. of turf to low water use landscape
- Scottsdale - up to $1,500 for turf removal at residential properties
  - up to $3,000 for commercial properties
- Peoria - up to $1,650 to convert 500 sq. ft. of turf to low water use landscape

Public Communication & Education
- Scottsdale: Green Buildings Lecture Series
Institutional Support

Federal Funding
- EPA Sustainable Skylines (Dallas, TX; Kansas, KS; Philadelphia, PA)
- Federal General Services Administration – Green Roof (Florence, SC)
- Department of Energy – “Trees for Energy Saving” (Denver, CO)

Partnerships – local municipalities, private and non-profit
- Local Energy Suppliers
  - “Trees for Tucson” tree subsidies (Tucson Electric Power, Trico Electric co-op, Kinder Morgan; Tucson, AZ)
  - Reflective roof rebates (Austin Energy, -Austin, TX; Cool Houston! - Houston, TX)
- Local non profits
  - Urban Forestry Program (Groundwork Elizabeth, Elizabeth, NJ)
- Gilbert, AZ currently seeking partnerships with other municipalities
Institutional Support

New building and development guidelines
- Green building codes for city and commercial buildings
- Requirements of cool roofs, shade and/or vegetative cover

Community outreach and involvement
- Educational meetings and workshops
- “Adopt-a-Median” tree planting program (Dallas, TX)
- Development of heat island and cool community task forces (Atlanta, GA; Philadelphia, PA, Austin, TX, others)
Goal: Assess socio-technical vulnerabilities at household level

Identify vulnerable social groups
- Income levels
- Housing styles
- Ethnicity
- Neighborhood
- Health

Evaluate technology & services
- Building use
- Hours of operation
- Transportation
- Marketing
- Services offered

Public Survey

Household characteristics
Long-term exposure to heat in urban areas is increasingly becoming a concern for residents within the City of Mesa. This survey will help the City of Mesa identify public risks associated with extreme heat exposure.

Select your gender *
- Male
- Female
- Prefer not to disclose

Select your age group *

Which of the following best represents your social/ethnic group? *
Select all that apply
- Non- Hispanic/White
- Hispanic or Latino
- Black or African American
- Hawaiian/Pacific Islander
- American Indian or Alaska Native
- Other

What type of housing do you primarily reside? *
Select all that apply
- Single-family housing
- Multifamily (apartment, condo, townhouse)
- Assisted living facility
- Other

Approximately what was the housing unit you live in constructed? *
Select the best option
- 1930's or before
- 1940's-1970's
- 1980's-1990's
- 2000 or later
Cooling Centers & Hydration Stations

Cooling Centers

Access Issues
- Proximity
- Availability ≤ 50% on Saturday and Sunday

Building Use
- Religious (13%)

Limited Services
- Conduct personal business
- Community engagement

Water distribution

Access Issues
- Proximity
- Seasonal

Waste produced
Improvements
Hydration Stations

Goal: Increase accessibility to water, improve water distribution

Solutions
- Water bottle filling stations
- Commercially endorsed water bottles

Benefits
- Quick, easy access
- Reusable – reduce waste
- Reduce distribution issues
- New image for old fountains

Continue to promote Mesa Hydration Donation Campaign
Heat Risk Education & Communication

**Education Efforts**
- Symptoms of heat illness
- Maximum safe exposure time
- When to seek medical help
- General safety tips

**Communicate Available Resources**
- Hydration and water bottle refill stations
- Cooling center locations
- Emergency information

**Communication Methods**
- Broadcast media
- Voluntary Emergency Message System
- Post information
- MesaAZ.gov website
Heat Vulnerability Council

Goal: Manage Heat Vulnerability Mitigation Plan & support program success

Small team comprising of
- City of Mesa officials
- Community stakeholders
- Concerned citizen volunteers

Successful Examples
- Philadelphia Heat Task Force
- El Paso’s Heat Task Force

Roles and Duties
- Review EHE best practices
- Update Heat Vulnerability Mitigation Plan
- Evaluate measures of success
Measures of Success

Goal: Develop measures to evaluate the effectiveness of efforts to reduce social heat vulnerability in Mesa, Arizona

Measures of Effectiveness
- # of heat-related hospitalizations (morbidity)
- # of heat-related deaths (mortality)
- Heat related emergency costs
- Ratio of person/sq. ft. area of accessible air conditioning
- # of persons utilizing cooling centers and hydration stations
Overview of Recommendations

TRANSPORTATION
- Roadway Improvements
- Expand transit services
- New paving materials
- Multimodal services

NEIGHBORHOODS & BUILDINGS
- Cool roofs
- Energy Production
- Heat Reduction
- Solar Light Tubes
- Facades

ENVIRONMENT
- Shading
- Tree Shading
- Improved Surfaces
- Stormwater infrastructure Improvement

SOCIAL & INSTITUTIONAL
- Education
- Heat Vulnerability Adaptation Plan
- Measures of Effectiveness
- Heat Vulnerability Council