CIVIL AND ENVIRONMENTAL ENGINEERING DEPARTMENT

Reducing Heat Exposure for Metrobus Riders in Washington, D.C.

CEE Team 16 - FTA1-2
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Project Description

Introduction: In July 2023, our planet reached unprecedented temperatures for four consecutive days in a row and set a record for the hottest day ever recorded. In conjunction with the urban heat island effect - a phenomenon where metropolitan development replaces green space - individuals who spend more time outdoors, such as those waiting at bus stops, are particularly vulnerable.

Goal and Objective:
The *Designing a Cooler Bus Stop* project seeks to reduce heat exposure for Metrobus users through the redesign of an existing bus shelter. The team's objective is to reduce the mean radiant temperature (MRT) of the selected bus shelter by 10º F.

Area of Interest

Selection Process: Ward → Bus Route → Bus Shelter

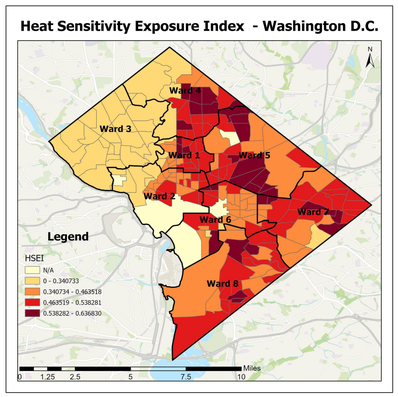

Figure 1. HSEI Map - District of Columbia

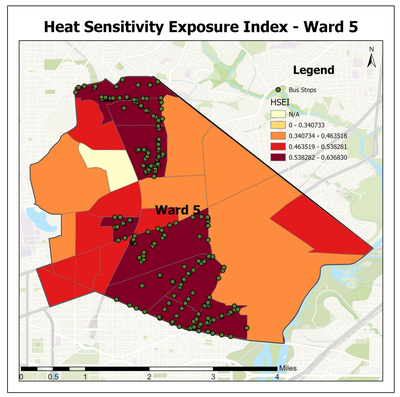

Figure 2. HSEI Map - Ward 5

Bus Route Decision Matrix					
Bus Route	% Stops in HSEI Zones	Line Benefit Score	Line Grade	Line Grade Score	Final Score
D8	59.70	28	C	20	39.08
80	30.77	42	C	20	33.11
E2	45.61	14	B	30	29.85
S41	80.00	7	-	0	34.80
D4	39.58	29	C	20	31.43
Weight	**0.4**	**0.4**	**-**	**0.2**	**-**

Table 1: Selected Routes and their Final Scores

Bus Shelter Decision Matrix: Route D8				
Stop ID	Tree Cover (%)	Impervious Surfaces (%)	Mean Air Temperature (°F)	Final Score
1001387	18.48	45.79	96.19	79.92
1001476	18.48	45.79	96.19	79.92
1001504	12.76	62.24	95.83	85.29
1001658	17.01	51.7	96.03	81.69
1001765	17.01	51.7	96.03	81.69
Weight	**0.25**	**0.25**	**0.5**	**-**

Table 2: Selected Bus Shelters and their Final Scores

Figure 3. Google Street View of Selected Bus Shelter

Cooling Strategy Selection

Strategy	Means of Cooling	Decision	Reasoning
Cool Roof	Solar Energy Reflectance	Yes	Capable of 50 - 60° F surface temperature reduction (1)
Green Roof	Urban Shade and Evapotranspiration	No	Structural and maintenance complications
Roof Overhang	Increased Shade Profile	Yes	Properly oriented overhangs can reduce MRT by approximately 12° F (2)
Cool Pavement	Solar Energy Reflectance	No	Increased exposure to solar radiation on pedestrian walkways
Trees and Vegetation	Natural Cover and Evapotranspiration	No	Interferences with utilities, overhead wires, and right-of-way

Table 3. Cooling Strategy Decision Matrix

Resources:
1) Center for Climate and Energy Solutions. (2017, November). *Resilience Strategies for Extreme Heat*. https://www.c2es.org/.
2) Middel, A., AlKhaled, S., Schneider, F. A., Hagen, B., & Coseo, P. (2021). *50 Grades of Shade*. Bulletin of the American Meteorological Society, 102(9). https://doi.org/10.1175/bams-d-20-0193.1

Structural Analysis

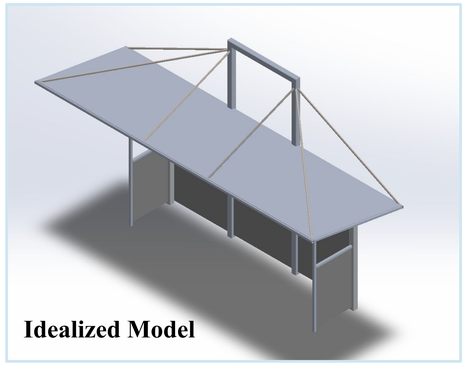

Figure 4. SolidWorks Output of Idealized Model

Design Loads
Dead Load: 32.17 ft/s^2
Snow Load: 30 psf
Wind Load: 48 psf

Results
Deflection: 0.1”
Axial Stress: 55 psi
Safety Factor: 3

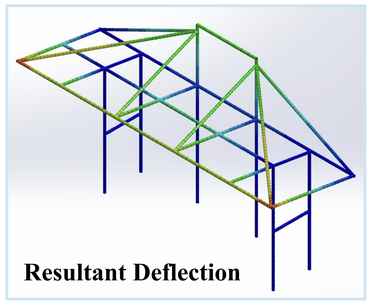

Figure 5. SolidWorks Output of Resultant Deflection

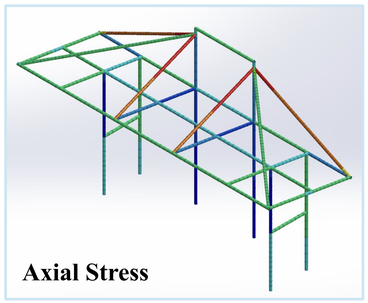

Figure 6. SolidWorks Output of Axial Stress

Proposed Design

Features
- 100% Larger Roof
- Side Ventilation Slats
- Cool Roof Coating
- Solar Panels

Estimated Cost
$19,140.21

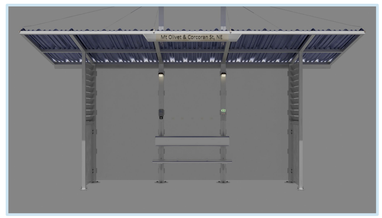

Figure 7. Proposed Design in Blender - Front View

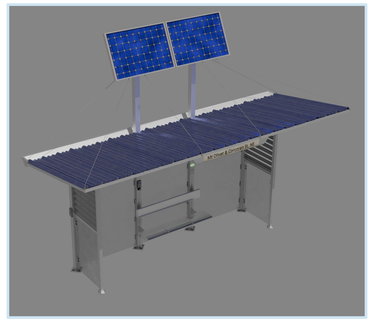

Figure 8. Proposed Design in Blender - Side View

Mean Radiant Temperature Simulations

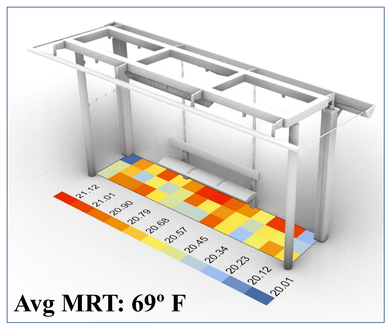

Figure 9. MRT Analysis Rhinoceros 3D - Existing Conditions

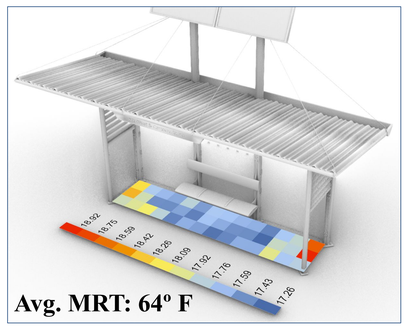

Figure 10. MRT Analysis Rhinoceros 3D - Proposed Conditions

Conclusion

Due to simulation limitations, the MRT was not reduced by 10º F. However, prior field studies suggest that a 10º F reduction is feasible.

Recommendations:
- Implement natural shade when feasible
- Construct properly oriented overhangs
- Use heat-mitigating materials, coatings, and films
- Pilot program with full-scale model

Acknowledgements

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