EFFECTIVENESS OF TRAVEL BEHAVIOR AND INFRASTRUCTURE CHANGE TO MITIGATE HEAT EXPOSURE

Rui Li[1]*, Mikhail V. Chester[1, 2, 3, 5], Ariane Middel[4,5,6], Jennifer K. Vanos[3], Danae Hernandez-Cortes[3,7], Isaac Newton Buo[8], David M. Hondula[4,5]

[1]School of Sustainable Engineering and Built Environment, Arizona State University, Tempe, AZ, USA; [2] Metis Center for Infrastructure and Sustainable Engineering, Arizona State University, Tempe, AZ, USA; [3] School of Sustainability, Arizona State University, Tempe, AZ 82581, USA; [4]School of Geographical Sciences and Urban Planning, Arizona State University, Tempe, AZ 85281, USA; [5] Global Institute of Sustainability and Innovation, Arizona State University, Tempe, AZ 85281, USA; [6] School of Arts, Media and Engineering and School of Computing, Informatics, and Decision Systems Engineering, Arizona State University, Tempe, AZ 85281, USA; [7]School for the Future of Innovation in Society, Arizona State University, Tempe, AZ 85281, USA; [8]Department of Geography, University of Tartu, Vanemuise 46, 50410, Tartu, Estonia

Overview

Urban heat exposure is an increasing health risk among urban dwellers. Many cities are considering accommodating active mobility, especially walking and biking, to reduce urban-induced anthropogenic greenhouse gas (GHG) emissions. However, promoting active mobility without proper planning and transportation infrastructure to combat extreme heat exposure may cause more heat-related morbidity and mortality in the climate change future. This study estimated the effectiveness of active trip heat exposure mitigation under built environment and travel behavior change. Simulations of the Phoenix Metropolitan Area's daily travel are conducted using a meso-scale travel behavior and exposure model (Icarus) to test how changing the built environment and behavior can reduce heat exposure.

Method - Icarus

This study focuses on 2,070 km^2 (800 square miles) of the urbanized Phoenix metro region, a 6% area of the Phoenix Metropolitan Area (Figure 1). 624,987 active trips are considered in the simulation. The simulation date is June 27th, 2012

Figure 1. Study area

The simulations are conducted in Icarus, a personal daily heat exposure simulation platform that estimates exposure considering everyone's activity and travel schedule, transportation infrastructure, environmental temperature, and the indoor/outdoor environment (Li et al., 2023).

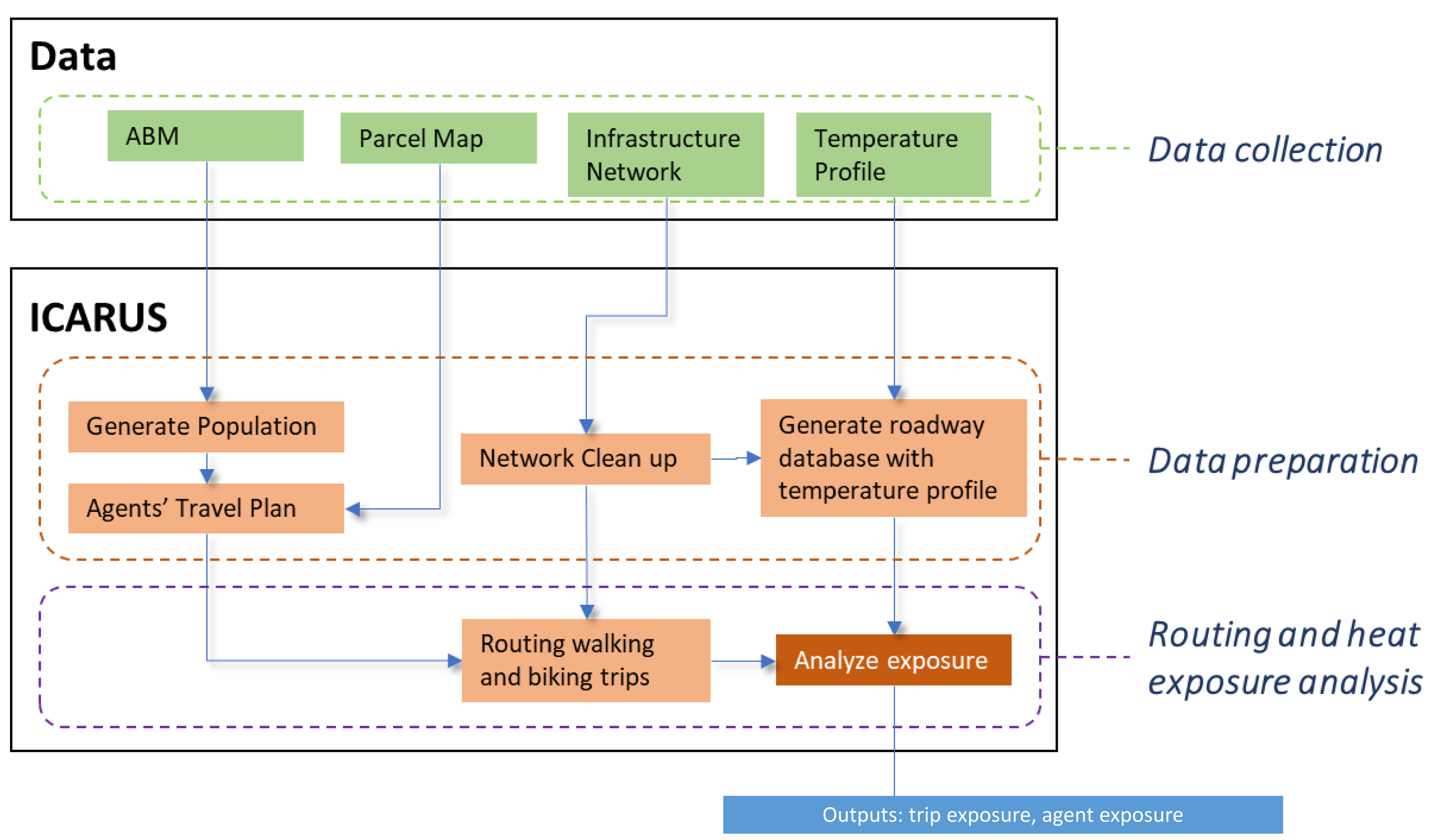

Figure 2. Icarus Framework

Method - Simulations

Three simulations are conducted to assess heat mitigation effects:

- Baseline simulation: captures heat exposure of active (walking and biking) trips as they prioritize the shortest travel distance.
- Change Built Environment Simulations: calculate trip heat exposure when a potion of the transportation network convert to cool environment. Two cooling scenarios are considered in simulation.
- Change Travel Behavior Simulations: calculate trip heat exposure when travelers rerouting to a cooler path with some extra distance.

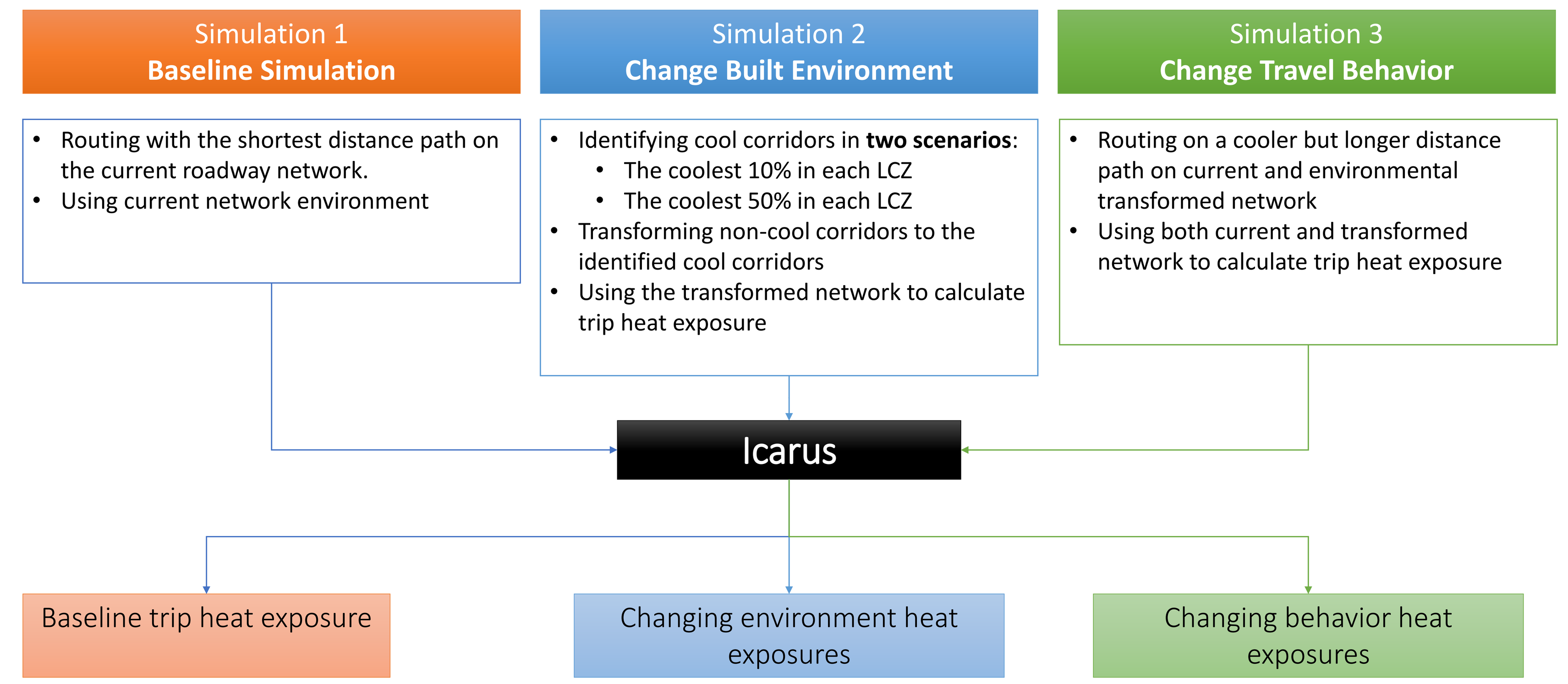

Figure 3. Simulation Setups

Local Climate Zone (LCZ) models, often used to describe the built environment characterizing geometric and land cover patterns (Stewart & Oke, 2012), are introduced to identify the high (low) –temperature roadways in the network.

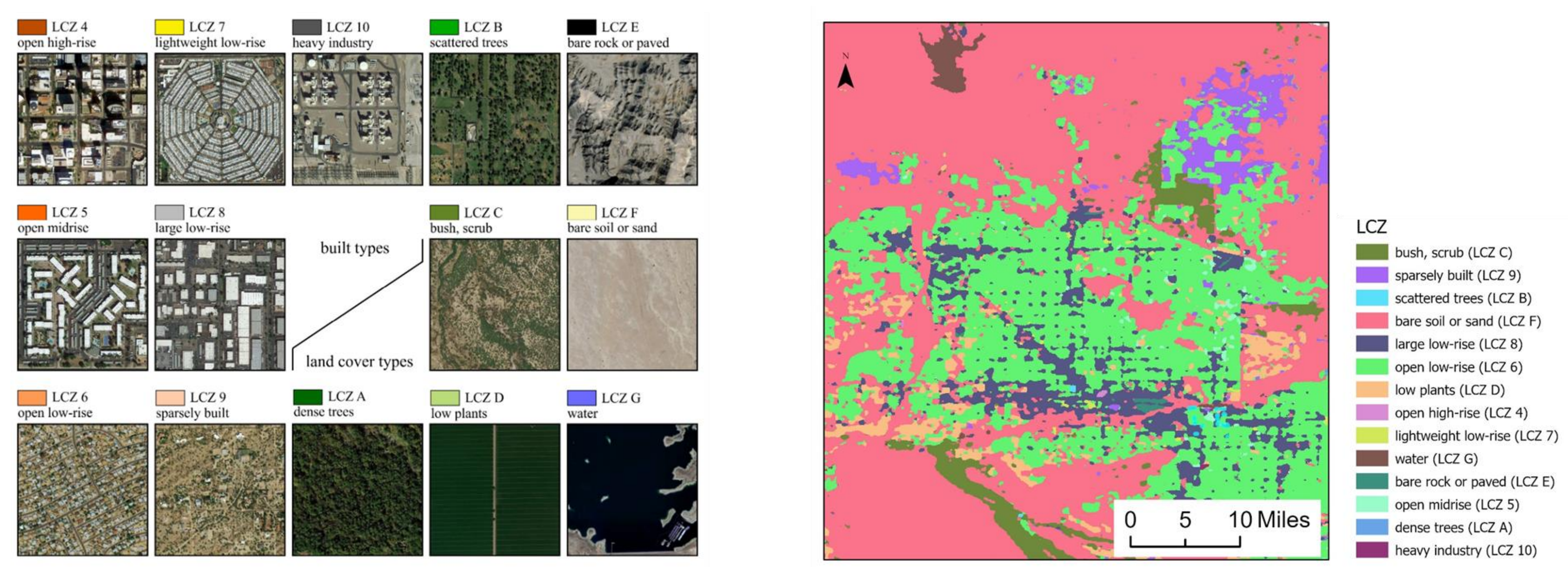

Figure 4. LCZ for Phoenix

Built environment change embraces the following assumptions:

- First, roadways with high-temperature can be cooled down to the low-temperature corridors in the same (LCZ) .
- Second, when corridors are selected for cooling, their Mean Radiant Temperature (T_{MRT}) can be cooled to the mean T_{MRT} of the low-temperature corridors in the same LCZ.

Result

Roadway location and temperature characteristics:

- Roadways in the study area are mainly located in LCZs with buildings.
- More trips happened on roadways in regions with mid-rise or low-rise buildings (LCZ 5, 6, and 8) or plants (LCZ D).
- The T_{MRT} in regions with middle to low-rise buildings and plants (LCZ 5, 6, 8, and D) is lower than in regions with sparse buildings or bare soil (LCZ 9 and F).
- Cool corridors in Scenario 1 (the coolest 10% corridors) had a lower T_{MRT} compared with Scenario 2 (the coolest 50% corridors).

Table 1. Filtering out the vulnerable trips

LCZ name	Total roadway length (km)	Ratio of roadway visited by active trips	% of land in this LCZ	% of road in this LCZ	T_{MRT} at 5 PM (°C)		
					Median (5%, 95%)	Target cooling temperature Scenario 1 *	Target cooling temperature Scenario 2 **
open low-rise (LCZ 6)	18,606	0.66	48%	58%	67 (58,78)	60	65
large low-rise (LCZ 8)	8,258	0.48	15%	26%	67 (58,73)	60	65
bare soil or sand (LCZ F)	3,431	0.29	27%	11%	71 (61,73)	64	68
sparsely built (LCZ 9)	647	0.05	0%	2%	71 (59,73)	61	68
low plants (LCZ D)	202	0.61	6%	1%	68 (62,72)	65	67
open midrise (LCZ 5)	562	0.50	1%	1%	64 (53,71)	56	61

* Scenario 1 selects cool corridors as the coolest 10% of roadways in each LCZ.
** Scenario 2 selects cool corridors as the coolest 50% of roadways in each LCZ.

Travelers experienced T_{MRT} heat exposure ranging from 29°C to 76°C (84°F to 168°F) on the simulation day. Behavior changing cooled up to ten times more trips than the built environment changing. Active trips reduced an average of 1.2°C to 3.7°C based on different scenarios when the networks were fully converted to the cool corridors. The marginal benefit of the cooling decreased from over 1,000 trips/km when less than 10 km of corridors were converted to less than 1 trip/km when all corridors were transformed.

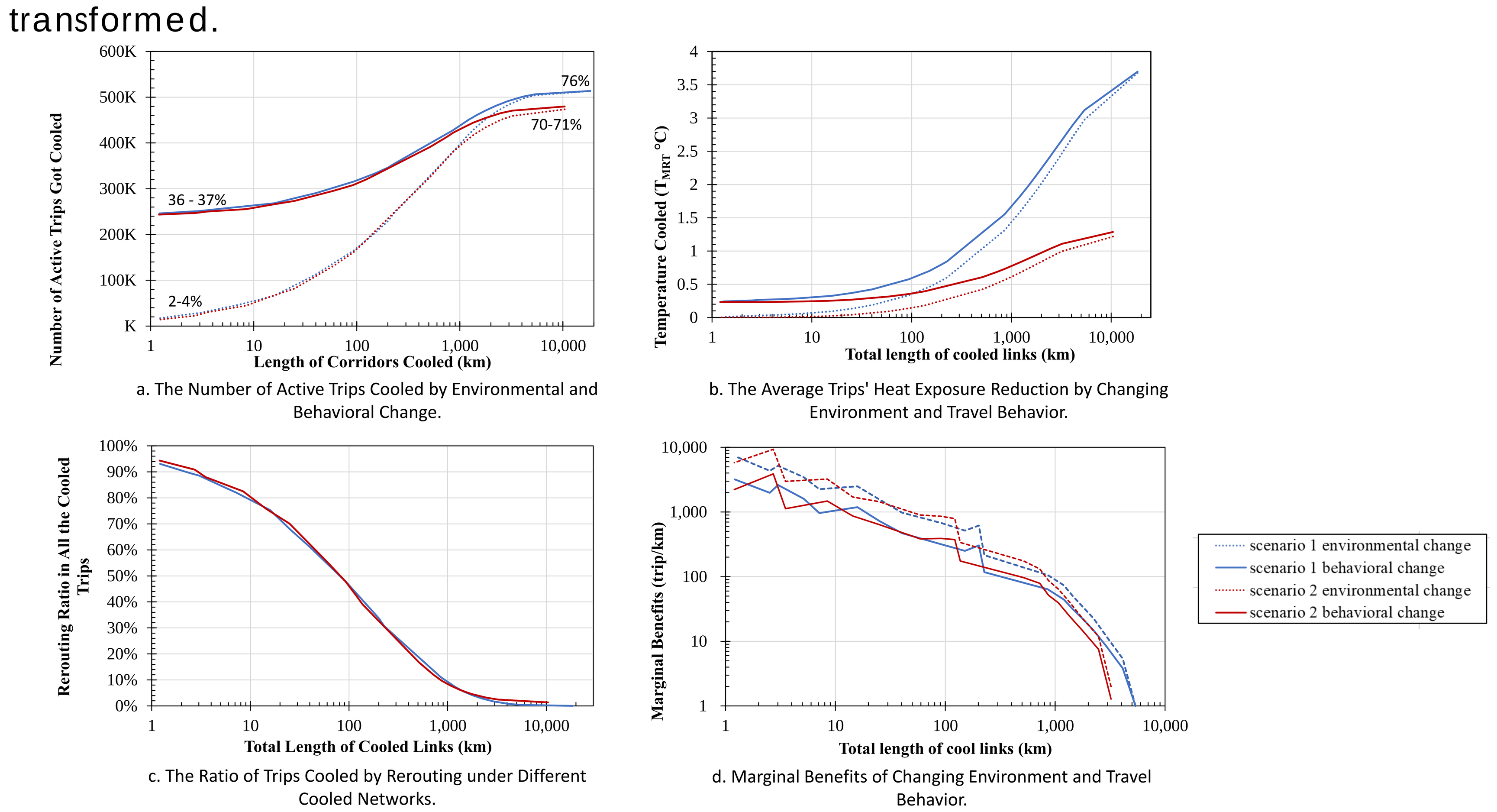

Table 1. Filtering out the vulnerable trips

Reference

Li, R., Chester, M. V., Hondula, D. M., Middel, A., Vanos, J. K., & Watkins, L. (2023). Repurposing mesoscale traffic models for insights into traveler heat exposure. Transportation Research Part D: Transport and Environment, 114, 103548. https://doi.org/10.1016/j.trd.2022.103548

Stewart, I. D., & Oke, T. R. (2012). Local climate zones for urban temperature studies. Bulletin of the American Meteorological Society, 93(12), 1879–1900. https://doi.org/10.1175/BAMS-D-11-00019.1

ruili11@asu.edu; mchester@asu.edu