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AN AGENT-BASED SOCIAL-GEOSPATIAL MODEL TO EVALUATE THE EFFECTIVENESS OF A TARGETED HEAT WARNING SYSTEM

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ABSTRACT

Extreme heat poses significant threats to vulnerable populations, and heat events now occur more frequently and are more severe and longer-lasting due to climate change. Research suggests that targeted building-specific heat warning systems could increase responsiveness to extreme heat events and save lives. To study this, an agent-based model integrating geospatial data with a dynamic social network was developed to simulate residents' responses to targeted heat alerts. Agent decisions are influenced by the strength of their social ties, transportation access, and spatial constraints. Experimental results indicate the importance of leveraging strong social connections, but the effectiveness of a targeted heat warning system may be limited if the challenges posed by transportation barriers and inadequate cooling centers remain unaddressed.

1 INTRODUCTION

Extreme heat, defined as weather that is much hotter and/or more humid than average for a particular time and place, is the leading weather-related cause of death in the US (NOAA 2023). Notably, the 1995 Midwest heatwave caused at least 739 deaths in Chicago, primarily among isolated elderly residents (Semenza et al. 1999). Many residents ignore extreme heat warnings due to mobility issues, safety concerns, caregiving responsibilities, or lack of transportation (Taylor et al. 2023). Moreover, existing warning systems cannot forecast building-specific indoor conditions, which depend on housing, microclimate, and occupant behavior (Taylor et al. 2023; Gustin et al. 2020). A growing body of research and policy focuses on heatwaves (Taylor et al. 2023), including research on accurately predicting indoor conditions of specific buildings to enable targeted warnings (Gustin et al. 2020). However, these warning systems' ability to motivate vulnerable residents to seek safety is unknown. To evaluate the effectiveness of a building-specific targeted heat warning system, an agent-based model (ABM) of a vulnerable neighborhood was developed using geospatial and social network data to understand how warning systems shape residents' responses.

2 AGENT-BASED MODEL OF CAPITOL EAST NEIGHBORHOOD

To improve the effectiveness of heat alerts, implementation of an app-based building-specific targeted heat warning system has been proposed (Passe et al. 2020). The purpose of the ABM described in this research is to evaluate the app's effectiveness in motivating vulnerable residents to move to safety. Model logic was developed using survey and microclimate data, socio-demographic features, and GIS-based spatial layers. Residents, residential buildings, cooling centers, and bus stations are modeled as agents. Each resident is assigned to a single building and defined by demographic characteristics and transportation access, as well as dynamic state variables such as location, social connections, and risk awareness. Residential buildings are characterized by physical and environmental attributes, such as air conditioning type, tree coverage, and current indoor heat index. Cooling centers are specified by their capacities. Using GIS, the model incorporates georeferenced coordinates of buildings, streets, bus stops, and cooling centers, allowing agents to make location-based decisions and ensuring that distances and travel times are calculated from actual neighborhood geometry. The ABM contains five sub-models, shown in Figure 1 and described below:

1. *Initialization*: A social network is created, assuming preferential attachment according to similarity. Each potential connection is assigned a utility score based on proximity, age, income, and years in the neighborhood, which determines a connection probability. If a sample of a uniform 0-1 random variable is below the probability, a mutual connection forms with strength proportional to the utility score.
2. *Indoor Temperature and Forecast Notification:* Indoor heat forecasts and advance heat risk notifications are generated for each resident, based on current outdoor conditions, surrounding tree coverage, and air conditioning type ("Central", "Window", "None"). Each evening at 7 PM, the model projects hourly indoor heat index values for each residence for the next day. These estimates determine whether a resident is at risk in any given hour. If the projected indoor temperature is 85°F or higher, the corresponding hour is marked as hazardous for the resident occupying that building.
3. *Making Protective Plans:* In response to an alert, residents will make plans, such as arranging to stay with friends, going to cooling centers, or remaining at home. Residents first try to rely on close social ties. If strong ties are unavailable, they may consider weaker ties, according to distance, availability, and number of visitors already present there. Otherwise, residents may plan to visit cooling centers, according to proximity and capacity. Travel modes include walking, driving, or taking the bus.
4. *Managing Dynamic Social Network:* The model treats social relationships as evolving connections that strengthen when residents help each other during heat waves, with tie strength increasing for each positive interaction and gradually weakening without interactions. Ties falling below a strength threshold are removed from both residents' networks.
5. *Executing Heat Wave Actions*: When a heat wave starts, residents who planned ahead carry out their chosen actions and return home afterward, and updates to relevant state variables are made.

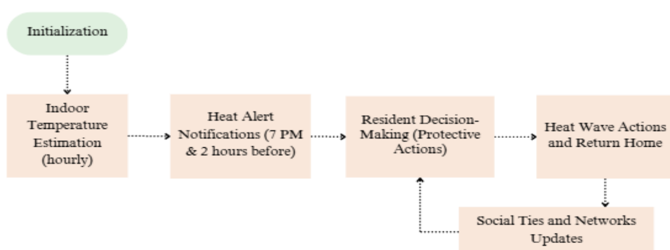

Figure 1: The overall framework.

To evaluate the system's effectiveness during a heat event, the simulation monitors the number of vulnerable non-safe residents who take protective action and the proportion of these residents that visits cooling centers and trusted friends' homes. Experiments compare outcomes with and without the proposed alert system in place, as well as scenarios with varying transportation and cooling center availability and social network structures. Ongoing work includes sensitivity analysis and validation of behavior patterns to inform equitable policy interventions, as well as the impact of adding alternative cooling center locations. Design and analysis of computer experiments and metamodeling will be employed to efficiently explore the ABM parameter space and identify the most influential factors in protecting vulnerable residents. This will help prioritize interventions and strengthen decision making for equitable adaptation strategies.

REFERENCES

National Oceanic and Atmospheric Administration. (2023). *Weather related fatality and injury statistics*. U.S. Department of Commerce. Retrieved November 26, 2024, from https://www.weather.gov/hazstat

Semenza, J. C., McCullough, J. E., Flanders, W. D., McGeehin, M. A., & Lumpkin, J. R. (1999). Excess hospital admissions during the July 1995 heat wave in Chicago. *American journal of preventive medicine*, *16*(4), 269-277.

Taylor, J., McLeod, R., Petrou, G., Hopfe, C., Mavrogianni, A., Castano-Rosa, R., ... & Lomas, K. (2023). Ten questions concerning residential overheating in Central and Northern Europe. Building and Environment, 234, 110154.

Gustin, M., McLeod, R. S., Lomas, K. J., Petrou, G., & Mavrogianni, A. (2020). A high-resolution indoor heat-health warning system for dwellings. Building and Environment, 168, 106519.

Passe, U., Dorneich, M., Krejci, C., Koupaei, D. M., Marmur, B., Shenk, L., ... & Zhou, Y. (2020). An urban modelling framework for climate resilience in low-resource neighbourhoods. Buildings and Cities, 1(1).