The Role of Prior Experience in Shaping Anticipated Travel and Activity Behavior Changes in Future Extreme Heat Events

Jinghai Huo[1], Irfan Batur*[1], Dale Robbennolt[2], Cynthia Chen[3], Chandra R. Bhat[2], Ram M. Pendyala[1]

[1] School of Sustainable Engineering and the Built Environment,

Arizona State University, Tempe, AZ, United States

[2] Department of Civil, Architectural and Environmental Engineering,

The University of Texas at Austin, Austin, TX, United States

[3] Department of Civil and Environmental Engineering,

University of Washington, Seattle, WA, United States

*Presenting author: ibatur@asu.edu

SHORT SUMMARY

Extreme heat events have been growing in intensity and frequency across the world, posing growing risks to public health, daily mobility, and community resilience. While behavioral adaptation is a critical coping mechanism during these events, the understanding of how prior experience shapes future adaptation choices is limited. This study addresses this by examining how the severity of past heat events influences anticipated future activity-travel choices. Using a nationwide survey data from the U.S., two multivariate econometric model systems are estimated – one for mobility choices and one for activity participation. Results reveal that perceived severity of prior extreme heat events directly affects anticipated behavioral adjustments, with individuals learning from experience to reduce heat exposure through decreased transit use, increased car use, staying home, and greater participation in indoor activities. It also found that vulnerable groups perceive heat impacts more intensely yet exhibit limited adaptation capacity, underscoring the need for targeted interventions.

Keywords: activity participation, behavioral adaptation, extreme heat, mobility choices

1. INTRODUCTION

The world is experiencing extreme weather events with greater intensity and frequency. The frequency of heat waves has increased dramatically from an average of two incidents per year during the 1960s to an average of six per year during the 2010s and 2020s in major US cities (U.S. EPA, 2025), with profound consequences for community wellbeing. While technological and urban design solutions such as air conditioning and increased tree cover can help mitigate extreme heat impacts, they are not always under the control of the individual. Behavioral adaptation – changes in activity-mobility choices and adjustments to daily routines – may have to be executed quickly to mitigate the impacts of extreme heat.

Considerable research attention has been paid to the deleterious effects of extreme heat (Hayden et al., 2017), behavioral adaptation mechanisms (Bauer, 2025; Zhao et al., 2023; Basu et al.,

2024), heat exposure experienced by different population segments (Hoehne et al., 2018), and the potential effectiveness of alternative heat adaptation strategies (Vargas et al., 2023). Mobility patterns show systematic behavioral adjustments, with overall mobility decreasing by up to 10 percent on hot days and 20 percent during hot afternoons (Renninger and Cabrera-Arnau, 2025). Transportation choices reveal complex adaptation strategies, with extreme heat increasing private vehicle use and reducing public transit and active transportation use (Batur et al., 2024; Bocker et al., 2016). Research has also shown that behavioral adaptations are non-uniform, with certain population groups, such as low-income households, often relying on immediate modifications that prove inadequate for sustained heat protection due to insufficient access to cooling resources (Batur et al., 2024).

Despite the vast body of research dedicated to understanding the impacts of, and mitigation strategies for, extreme heat events, there are no studies that systematically examine how prior experiences with extreme heat events (learning through experience) shape future behavioral adaptation choices. This represents a significant gap in understanding how the intensity of past heat impacts – ranging from minimal discomfort to severe health, economic, or daily life disruptions – influences subsequent adaptive decision-making. This gap in understanding how the severity and experience of prior heat events drive learning processes and adjustments in behavioral response makes it difficult to predict how individuals might modify their behaviors in response to increasingly severe heat events in the future. In the absence of this predictive capacity, it is difficult to proactively design effective interventions, align community resources, and develop targeted awareness efforts that promote optimal personal resilience and adaptation strategies across different contexts – particularly within transportation systems.

This study focuses, therefore, on addressing this fundamental gap by investigating how the severity of impacts of past heat events influences future decisions regarding behavioral adjustments to extremely hot temperatures, with a specific focus on travel choices and activity modifications. By identifying how different levels of prior heat event severity (from minimal to extreme) shape specific adaptive behaviors, this research provides insights for predicting individual heat response patterns in the future. The findings are intended to inform the development and design of targeted interventions and community resources that would best protect people from extreme heat.

DATA

The data used in this study are derived from the Community Adaptation and Resilience to Extremes (CARE) survey conducted from August 2024 through February 2025. The sample consisted of adults residing in the United States, with oversampling in the Greater Phoenix metropolitan region and the Greater Seattle area. The survey gathered detailed socio-economic and demographic data, attitudinal information, and accounts of past experiences with extreme events and anticipated behavioral responses to future events. A total of 5,082 responses were obtained through the Qualtrics platform via a commercial online panel.

A random subset of those who reported ever experiencing extreme heat was asked follow-up questions about the impact of their most recent event and how they would adjust their activity-travel patterns if it were to occur again. After removing cases due to inconsistent responses from this random subsample, the analytical sample comprised 2,648 respondents.

The survey asked respondents to rate the severity of impact of their most recent extreme heat event on their daily life on a five-point ordinal scale (not severe at all to extremely severe). A subset of these respondents was then asked how their activity-travel patterns would change (less,

same, or more) for a future similar event across eight behavioral dimensions: car use, public transit use, staying at home, dine-in/takeout, meal delivery, working from home, working from the office, and going about business as usual. Figure 1 presents the distributions of these endogenous outcome variables. It is worth noting that for most behavioral dimensions, a substantial share of respondents anticipate increasing their use of sheltered options – such as car use, staying home, and meal delivery – while transit use and going about business as usual show marked tendencies toward reduction, providing early descriptive evidence consistent with the modeling results presented later.

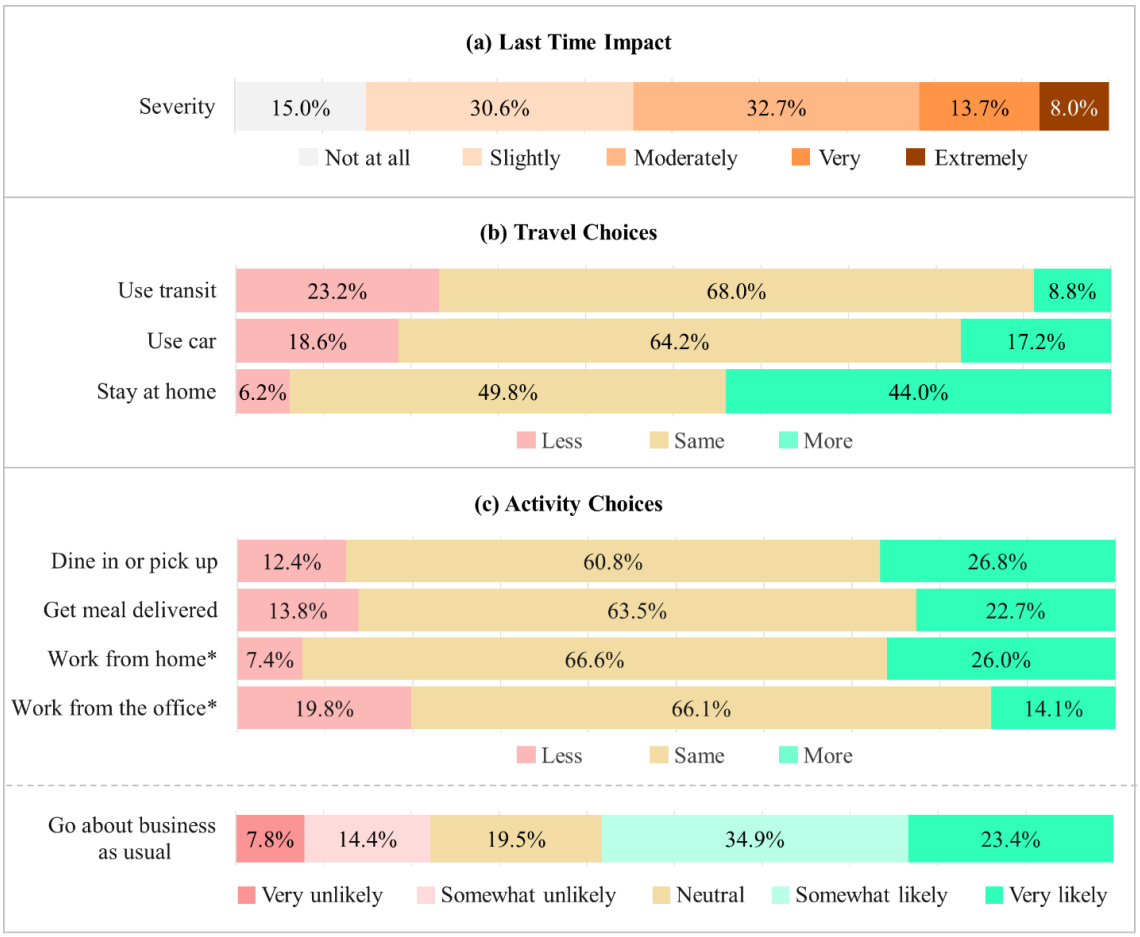


Figure 1. Distribution of Main Outcome Variables (N=2,648) | *(*) Asked Only to Workers*

The survey also included a battery of attitudinal statements used to develop three stochastic latent attitudinal constructs (Figure 2). The first, *Social Interaction Propensity*, captures the extent to which individuals enjoy meeting people unexpectedly, feel energized in group settings, and regularly participate in community activities. The second, *Community Support Capacity*, reflects perceptions of community cohesion during extreme events – including beliefs about community solidarity, the availability of nearby family or friends for immediate help, and the effectiveness of local communication channels. The third, *Personal Resilience*, is defined by the degree to which individuals feel they can personally bounce back quickly from challenging situations and are knowledgeable about the steps needed to ensure their safety during extreme events. These constructs are jointly estimated with the outcome variables, allowing them to simultaneously shape perceived severity and anticipated behavioral responses while accounting for otherwise unexplained correlations across outcomes.

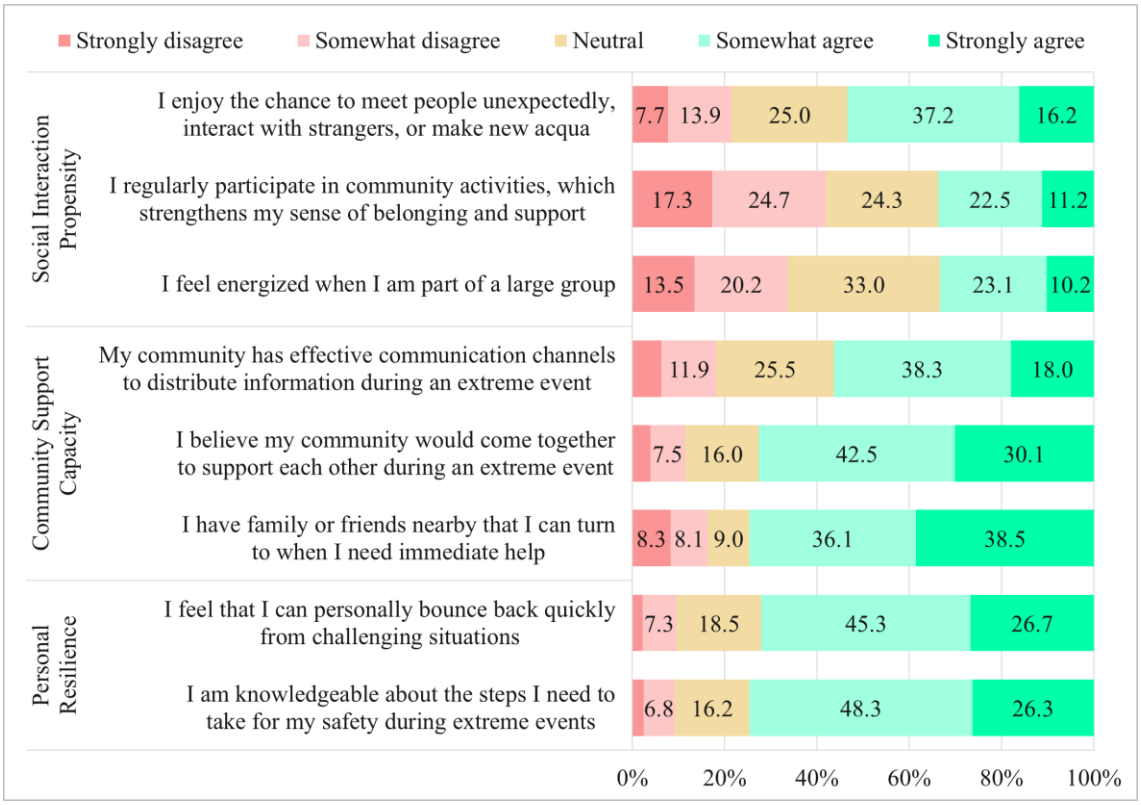


Figure 2. Agreement with Attitudinal Indicators Defining Latent Constructs (N=2,648)

2. METHODOLOGY

Two separate multivariate econometric model systems are estimated, one focusing on travel mode choices and the other on activity participation changes. In each model, the perceived severity of the last extreme heat event is treated as an endogenous variable jointly modeled with the anticipated behavioral responses, accounting for the simultaneity of experience and adaptation. Given their structural similarity, a simplified schematic of both models is presented in a single figure (Figure 3).

The models are formulated and estimated within the Generalized Heterogeneous Data Model (GHDM) framework developed by Bhat (2015). The GHDM accommodates mixed types of dependent variables (ordered and binary), stochastic latent constructs with loadings on attitudinal indicators, and embedded error correlation structures that engender correlations among outcome variables. Interested readers are referred to Bhat (2015) and Bhat and Mondal (2022) for a complete treatment of the GHDM formulation.

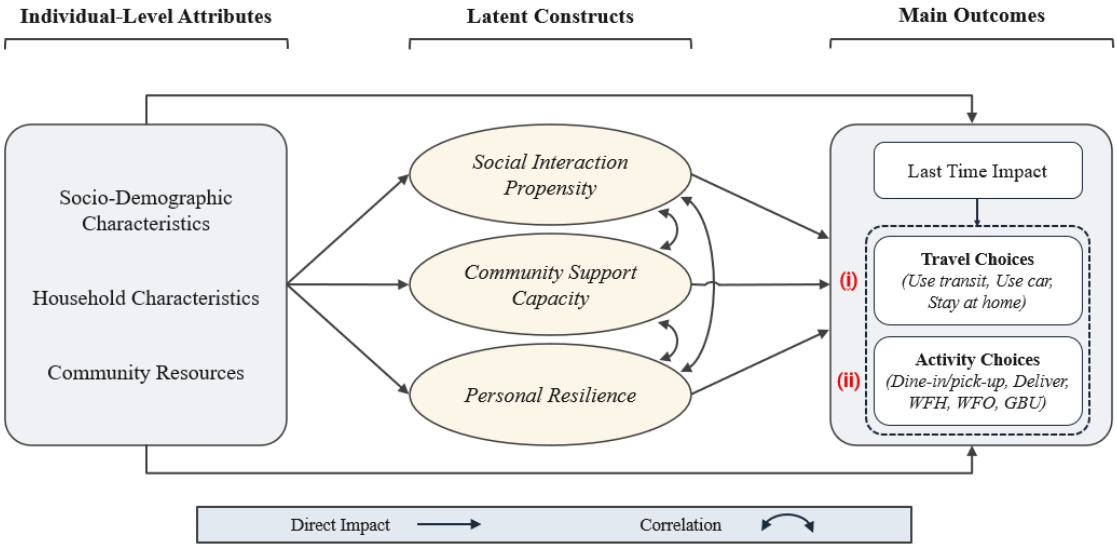


Figure 3. Model Framework: (i) Travel Choices; (ii) Activity Choices

3. RESULTS

Both model systems yield estimation results that are behaviorally intuitive and meaningful. Across the two models, socio-economic and demographic variables, the three latent constructs, and the endogenous severity variable all produce effects that are consistent with a priori expectations and with the broader literature on heat adaptations and activity-travel behaviors. For instance, higher social interaction propensity is associated with greater perceived severity and a tendency to increase car use and dine out – reflecting the behavioral pull of social engagement even under adverse conditions. Higher personal resilience is associated with lower perceived severity and a greater likelihood of going about business as usual, while higher community support capacity mitigates severity perceptions, particularly among older adults. Due to space limitations, full estimation results are not presented here.

Overall, the model estimation results reveal important patterns of heterogeneity across socio-demographic groups. Individuals with higher perceived severity – disproportionately low-income households, zero-car households, those with travel-limiting conditions, outdoor workers, and younger individuals – are precisely those who face the greatest structural constraints on behavioral adaptation. Low-income individuals, for instance, perceive a higher level of impact severity from extreme heat but are less likely to increase car use or work from home, reflecting limited access to vehicles and occupations with telework flexibilities. Zero-car households similarly perceive higher severity and plan to increase transit use and stay home more, but these responses are constrained by the very absence of a car. Outdoor workers anticipate increasing transit use during future heat events, suggesting that transit may function as a shelter for this group in the absence of other cooling options. In contrast, individuals with air conditioning at home, higher incomes, and personal resilience scores show lower perceived severity and greater adaptive capacity – evidenced by higher likelihoods of working from home, using meal delivery services, and going about business as usual when faced with a future heat event.

To communicate the substantive magnitude of the effects of prior experience on behavioral adaptation, Average Treatment Effects (ATEs) are computed following Bhat and Eluru (2009). ATEs measure the difference in average outcomes between a treatment group and a control (baseline)

group. In this study, the treatment represents a transition in perceived severity of the most recent extreme heat event experienced by an individual, from a baseline level of low severity (not at all severe or slightly severe) to a treatment level of high severity (moderately, very, or extremely severe). The resulting ATEs quantify the change in the proportion of individuals engaging in specific travel or activity behaviors due to this shift in perceived severity. Essentially, ATEs reflect the average causal effect of a treatment on an outcome variable, measured as the difference between what would happen with and without the treatment.

For computational convenience and ease of interpretation, the original ordered outcome variables in both models were transformed into binary variables. For the three-level ordered response variables (i.e., travel and activity engagement variables), the binary response groups are "*more*" and "*same or less*". For the five-level ordinal variable, Go About Business as Usual, responses were grouped into "*likely*" ("very likely" and "somewhat likely") and "*unlikely*" ("very unlikely", "somewhat unlikely", and "neutral").

Figure 4 presents the computed ATEs and Percent Average Treatment Effects (PATEs) for each behavioral outcome. Outcomes are organized into two groups – travel mode choices and activity engagement – and the bars represent the estimated average change in probability of selecting the "*more*" response category relative to a baseline of low-severity experience (for travel and activity outcomes), or the "*likely*" response category (for going about business as usual).

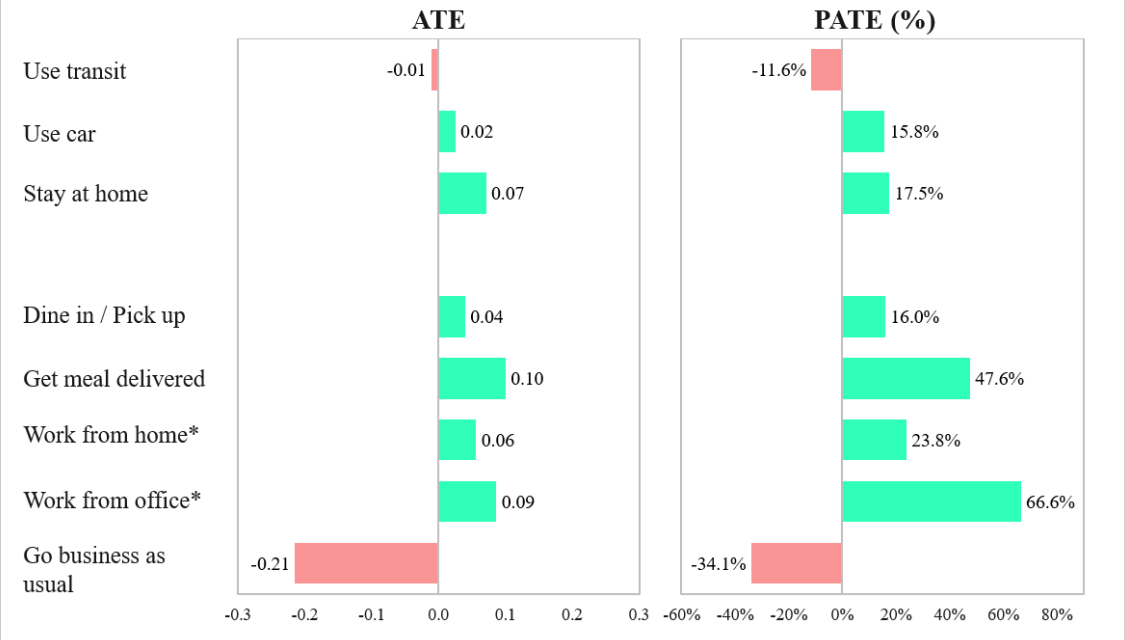


Figure 4. Average Treatment Effects for Travel and Activity Engagement Due to Change in Extreme Heat Event Severity Level | *(*) Limited to Worker-only Sample*

For travel mode choices, the ATE for car use is 0.02, corresponding to a PATE of 15.8 percent – meaning that transitioning from low- to high-severity prior experience increases the share of individuals anticipating more car use by 15.8 percent relative to the baseline. Stay-at-home behavior shows a similar effect. In contrast, transit use shows a negative treatment effect, consistent with the notion that transit exposes riders to outdoor heat and is therefore reduced when experience severity is high. These results indicate that individuals learn from prior experience to shift toward sheltered, car-based modes and to minimize exposure to outdoor environments.

For activity participation, the behaviors that exhibit relatively large PATEs include having meals delivered (PATE: 24.6%), working from home, and working from office – all of which represent indoor, climate-controlled alternatives to outdoor or transit-dependent activities. These findings confirm that individuals who have experienced more severe heat events are more inclined to seek thermal shelter through their activity choices. The most striking finding concerns going about business as usual: the ATE is -0.21 (PATE: -34.1%), indicating that a severe prior experience dramatically reduces the likelihood of maintaining habitual routines. Taken together, the ATE results paint a consistent picture of experience-driven behavioral learning: higher-severity prior experience amplifies adaptive adjustments to routines and increases engagement with thermally sheltered alternatives.

4. CONCLUSIONS

This study contributes evidence that prior experience with extreme heat serves as a meaningful learning mechanism that shapes anticipated behavioral adaptation. Using data from a nationwide survey in the U.S., two multivariate econometric model systems are estimated – one for mobility choices and one for activity participation. The key finding is that perceived severity of the most recent extreme heat event directly and significantly affects anticipated changes in activity-travel participation when a future event occurs. Higher-severity prior experience leads individuals to seek thermally sheltered options – increasing car use, staying home, shifting to food delivery, and working remotely – while reducing transit use and going about business as usual.

The model estimation results revealed a number of disadvantaged groups that are likely to feel the deleterious effects of extreme heat events and do not necessarily have the degrees of freedom necessary to shelter from the heat. Young individuals who are less experienced in coping with extreme events, individuals with mobility limitations, individuals in zero-car households, individuals in low income households, outdoor workers, and lower educated individuals who are likely in occupations that do not provide much flexibility, are all found to perceive the effects of extreme heat events more intensively and yet do not have the flexibility, resources, awareness, and wherewithal to modify their mode use and activity participation behaviors to mitigate the effects of extreme heat events if and when they occur in the future.

The findings suggest that communities need to develop targeted interventions for these vulnerable groups. These include subsidized door-to-door air-conditioned transportation for low-income and car-free households, subsidized air-conditioning installation or access to cooling centers with transportation assistance for those who cannot reach them independently, and subsidized delivery services for essential goods during extreme heat events. Models such as those presented in this paper can also be used to forecast activity-travel demand by purpose, modality, and mode of transportation on extreme heat days so that service levels can be modified accordingly to better serve the needs of the community.

ACKNOWLEDGEMENTS

This research was partially supported by the National Science Foundation through grants 2053373, 2128856, and 1828010, and by the National Center for Understanding Future Travel Behavior and Demand (TBD), a National University Transportation Center sponsored by the US Department of Transportation under grant numbers 69A3552344815 and 69A3552348320.

REFERENCES

Basu, R., Colaninno, N., Alhassan, A., and Sevtsuk, A. (2024). Hot and Bothered: Exploring the Effect of Heat on Pedestrian Route Choice Behavior and Accessibility. *Cities*, 155, 105435.

Batur, I., Alhassan, V.O., Chester, M.V., Polzin, S.E., Chen, C., Bhat, C.R., and Pendyala, R.M. (2024). Understanding How Extreme Heat Impacts Human Activity-Mobility and Time Use Patterns. *Transportation Research Part D: Transport and Environment*, 136, 104431.

Bauer, A. (2025). Working from Home as an Adaptation Strategy to Heat: Comparing Temperatures and Workers' Assessments for 203 Offices and 107 Homes. *Building and Environment*, 272, 112680.

Bhat, C.R. (2015). A New Generalized Heterogeneous Data Model (GHDM) to Jointly Model Mixed Types of Dependent Variables. *Transportation Research Part B: Methodological*, 79, 50-77.

Bhat, C.R., and Eluru, N. (2009). A Copula-Based Approach to Accommodate Residential Self-Selection Effects in Travel Behavior Modeling. *Transportation Research Part B: Methodological*, 43(7), 749-765.

Bhat, C.R., and Mondal, A. (2022). A New Flexible Generalized Heterogeneous Data Model (GHDM) with an Application to Examine the Effect of High Density Neighborhood Living on Bicycling Frequency. *Transportation Research Part B: Methodological*, 164, 244-266.

Bocker, L., Dijst, M., and Faber, J. (2016). Weather, Transport Mode Choices and Emotional Travel Experiences. *Transportation Research Part A: Policy and Practice*, 94, 360-373.

Hayden, M.H., Wilhelmi, O.V., Banerjee, D., Greasby, T., Cavanaugh, J.L., Nepal, V., Boehnert, J., Sain, S., Burghardt, C., and Gower, S. (2017). Adaptive Capacity to Extreme Heat: Results from a Household Survey in Houston, Texas. *Weather, Climate, and Society*, 9(4), 787-799.

Hoehne, C.G., Hondula, D.M., Chester, M.V., Eisenman, D.P., Middel, A., Fraser, A.M., Watkins, L., and Gerster, K. (2018). Heat Exposure During Outdoor Activities in the US Varies Significantly by City, Demography, and Activity. *Health & Place*, 54, 1-10.

Renninger, A., & Cabrera-Arnau, C. (2025). Spanish heat waves curb discretionary mobility and alter work behavior. *arXiv e-prints*, arXiv-2501.

U.S. Environmental Protection Agency. (2025). Climate Change Indicators: Heat Waves. U.S. Environmental Protection Agency. https://www.epa.gov/climate-indicators/climate-change-indicators-heat-waves

Vargas, N. T., Schlader, Z. J., Jay, O., & Hunter, A. (2023). Prioritize research on human behaviour during extreme heat. *Nature Human Behaviour*, *7*(4), 473-474.

Zhao, Q., Li, Z., Shah, D., Fischer, H., Solís, P., & Wentz, E. (2023). Understanding the interaction between human activities and physical health under extreme heat environment in Phoenix, Arizona. *Health & Place*, *79*, 102691.