ABSTRACT

Increased frequency and intensity of disasters necessitate the dynamic post-disaster recovery process. Developing human mobility patterns, household return decision-making models, and agent-based simulations in disaster management has opened a new door towards more intricate and enduring recovery frameworks. Despite these opportunities, the importance of a unified framework is underestimated to identify the underlying mechanisms hindering the post-disaster recovery process. My research has been geared towards forging advancements in civil and disaster management, focusing on two main areas: (1) modeling the post-disaster recovery process and (2) identifying critical transitions within the recovery process.

My dissertation explores the collective and individual dynamics of post-disaster recovery across different spatial and temporal scales. I have identified the best recovery strategies for various contexts by constructing data-driven socio-physical multi-agent systems. Employing various advanced computational methodologies, including machine learning, system dynamics, causal discovery, econometrics, and network analysis, has been instrumental. I start with aggregated level analysis for post-disaster recovery. Initially, I examined the system dynamics model for the post-discovery recovery process in socio-physical systems, using normalized visit density of points of interest and power outage information. Through counterfactual analyses of budget allocation strategies, I discovered their significant impact on recovery trajectories, noting that specific budget allocations substantially enhance recovery patterns. I also revealed the urban-rural dissimilarity by the data-driven causal discovery approach. I utilized county-level normalized visit density of points of interest and nighttime light data to identify the relationship between counties. I found that urban and rural areas have similar but different recovery patterns across different types of points of interest.

Moving from aggregated to disaggregated level analysis on post-disaster recovery, I investigated household-level decision-making regarding disaster-induced evacuation and return behaviors. The model yielded insights into the varying influences of certain variables across urban and rural contexts. Subsequently, I developed a unified framework integrating aggregated and disaggregated level analyses through multilayer multi-agent systems to model significant shifts in the post-disaster recovery process. I evaluated various scenarios to pinpoint

conditions for boosting recovery and assessing the effects of different intervention strategies on these transitions. Lastly, a comparison between mathematical models and graph convolutional networks was conducted to better understand the conditions leading to critical transitions in the recovery process.

The insights and methodologies presented in this dissertation contribute to the broader understanding of the disaster recovery process in complex urban systems, advocating for a shift towards a unified framework over individual models. By harnessing big data and complex systems modeling, I can achieve a detailed quantitative analysis of the disaster recovery process, including critical transition conditions of the post-disaster recovery. This approach facilitates the evaluation of such recovery policies through inter-regional comparisons and the testing of various policy interventions in counterfactual scenarios.