ABSTRACT

The magnitude and impact of natural disasters have seen an exponential increase in recent years. The total cost of natural disasters in the United States for the last five years ($742.1 billion) is more than one-third of the disaster cost total of the last 42 years ($2.155 trillion) (Smith, 2022). The impact of these events on the population and the economy varies significantly depending on the community's ability to cope with disasters. While accurately predicting the timing and magnitude of such events is almost always impossible, their effects can be mitigated by carefully understanding the social and physical factors contributing to post-disaster damage. To that end, understanding the vulnerability of communities and infrastructure against natural disasters has emerged as a viable approach in disaster management for quantifying and, eventually, mitigating the impacts of natural disasters.

Within the last two decades, substantial research has focused on establishing robust methods for measuring social vulnerability across different scales and locations. Existing methods for constructing social vulnerability indices often rely on subjective criteria and lack robustness. Common methodologies include Composite Indicators, Principal Component Analysis (PCA), and Multi-Criteria Decision-Making Analysis (MCDA). Limitations of the current methods stem from the difficulty in accounting for demographic heterogeneities in modeling, efficiently utilizing real-time disaster impact data streams and subjectivity in selecting criteria weights.

This dissertation investigates several new quantitative decision-making methods to quantify a region's vulnerability to natural hazards and overcome the shortcomings of the existing vulnerability modeling methods. In the first topic, we proposed a new vulnerability index construction method that can explicitly account for spatial heterogeneities in vulnerability

characteristics of local populations. In the second topic, we developed a non-compensatory composite indicator for vulnerability analysis. This approach is particularly useful when there are aspects of vulnerability in which compensatory trade-offs cannot be made against each other, as each criterion contributes uniquely to the overall assessment. The final task of the research proposed a time-varying vulnerability index against health emergencies, particularly pandemics. This approach is useful for real-time decision making for efficient allocation of resources to the region's specific needs.

The proposed methodologies were rigorously demonstrated using real disaster data and their performance was compared to existing methods from the literature. It has been shown that the proposed methods address several critical shortcomings of the existing methods and attained improved accuracy, objectivity, and applicability of social vulnerability indices in decision-making and resource allocation. For example, robust methods of measuring social vulnerability would be crucial for insurance companies to price their risk exposure into their premiums more accurately. Furthermore, it has been demonstrated how relief agencies could use the proposed non-compensatory vulnerability indicators to efficiently allocate relief resources to more vulnerable areas so that post-disaster recovery time can be decreased and, those needing the most assistance can receive it quickly.