Post-Hurricane Power Outage Recovery: Examining the Influence of Social Vulnerability, Economic Activity, and Critical Facilities

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Framework

Problem Statement

- Natural hazards are among the leading causes of major power outages due to the combined impacts of hurricanes, heavy rainfall, thunderstorms, storm surge, strong winds, and other extreme weather conditions that damage power and public infrastructure.
- Power outages following hurricanes disrupt social welfare, business operations, and the functioning of public facilities in the affected areas. Extended outages can severely impact communities, economic activities, and critical services.
- Recovery may not be uniform across affected areas due to differences in infrastructure, resource availability, accessibility, and community vulnerability. This study assesses how these factors influence outage recovery across impacted communities.

Social Vulnerability Index (SVI)

- Previous studies have shown that socioeconomic conditions can influence power restoration, with disadvantaged communities often experiencing longer outages and greater recovery burdens.
- Common vulnerability indices, such as SoVI and CDC-SVI, are widely used to assess community resilience to various types of environmental hazards. However, these generalized indices may not fully capture hurricane-related power outage impacts and recovery challenges.
- Therefore, this study develops a more targeted socioeconomic index, based on methods established in the literature, incorporating factors related to health, preparedness, and evacuation during hurricane events.
- A customized outage-focused Social Vulnerability Index (SVI) was developed to better capture community vulnerability to hurricane-related power disruptions.

Spatial Regression

- This study analyzes power outage recovery trajectories across 27 U.S. states affected by 21 hurricanes between 2017 - 2024. We assess whether counties' socioeconomic vulnerability, levels of economic activity, and the number of critical facilities consistently explain differences in post-hurricane power outage recovery time.
- Three spatial regression models, including the Spatial Durbin Model (SDM), Spatial Autoregressive Model (SAR), and Spatial Error Model (SEM), were applied to analyze recovery in affected counties across outage severity thresholds of ≥5%, ≥10%, ≥20%, ≥30%, ≥40%, and ≥50%, with outage durations of at least 60 minutes.
- Model performance, spatial dependence, and model suitability were assessed using multiple statistical evaluation metrics and diagnostic tests to ensure reliable spatial analysis results.

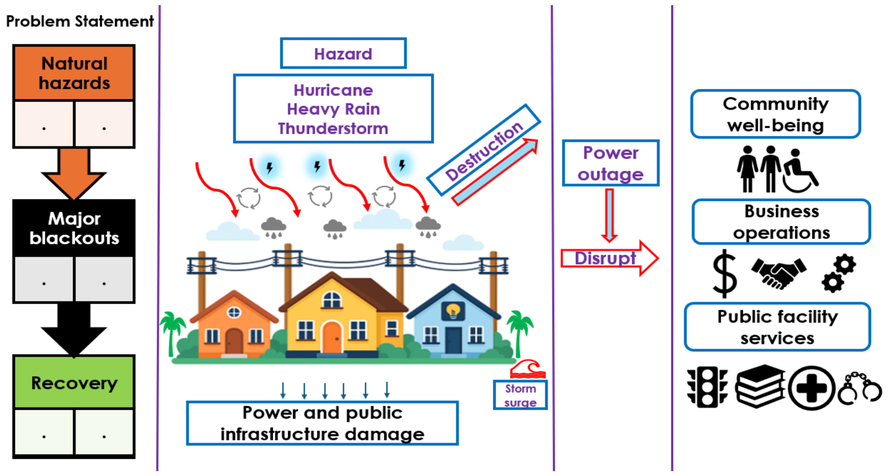
Limitations

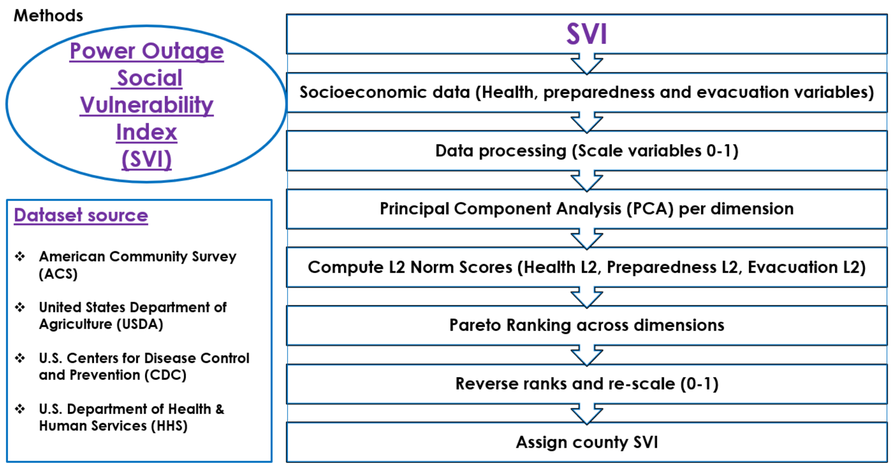
- Some outage percentages exceed 100%, indicating possible data inconsistencies.
- Outage data lacks information on utility power system resources.
- Finer scale analysis is required (e.g. census track level).
- Alternative recovery metrics that better represent power system robustness are required.

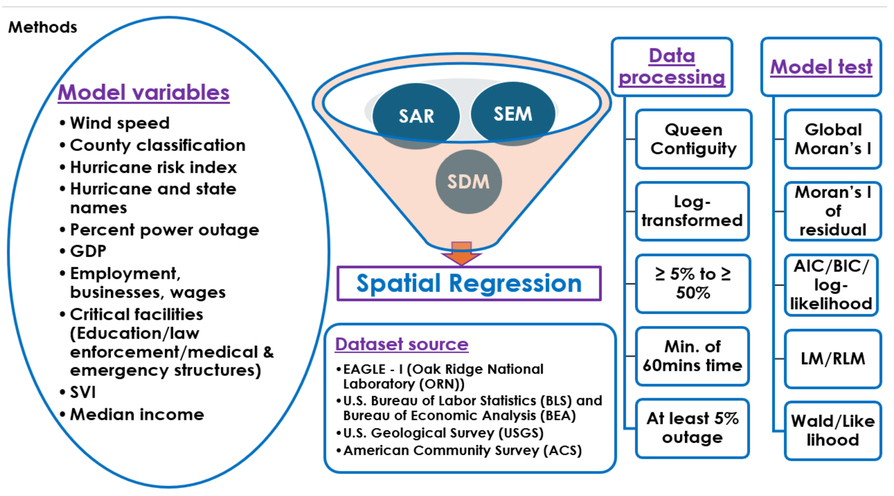
Takeaways

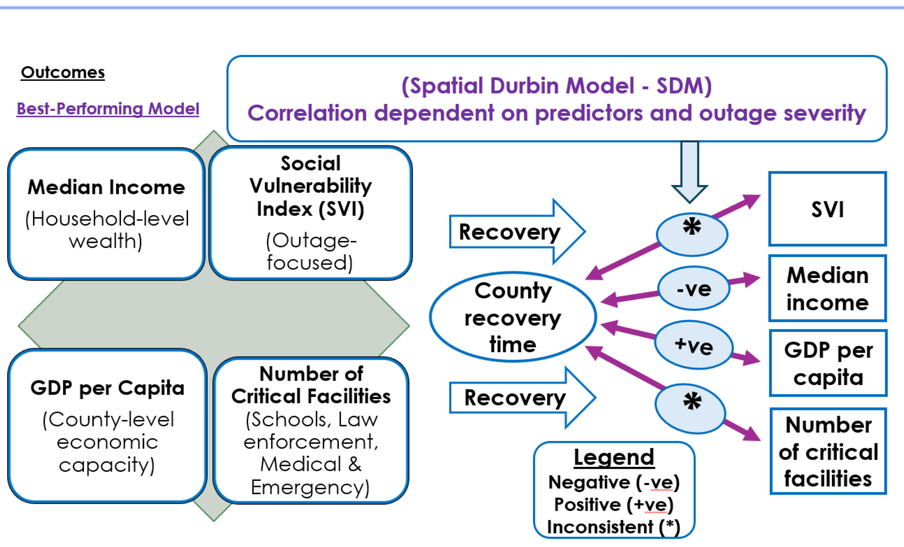
- Allocate additional recovery resources to outage-vulnerable communities.
- Invest in energy storage systems and backup-powered emergency shelters.
- Improve resilience through modern and underground power infrastructure in vulnerable areas.

Methodology

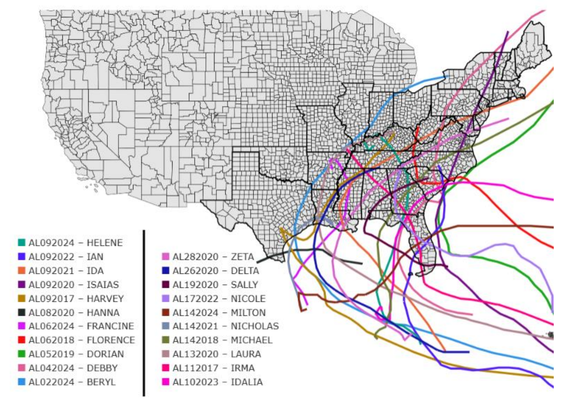




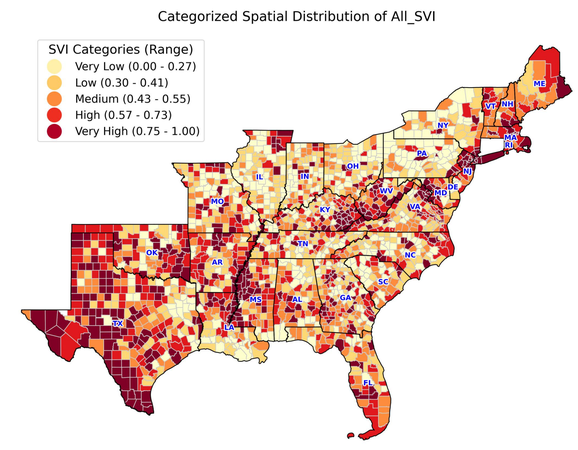




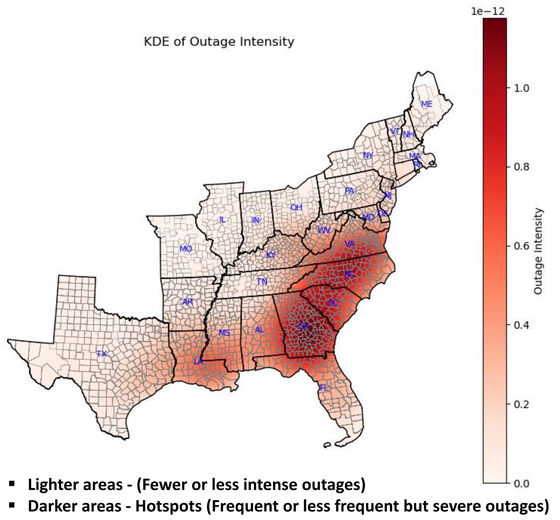
Results



21 Hurricanes (Category 1-5), 27 States - 2519 Total Affected Counties (2017-2024)



Health, Preparedness, and Evacuation Vulnerability Index



- Lighter areas - (Fewer or less intense outages)
- Darker areas - Hotspots (Frequent or less frequent but severe outages)

Conclusions

SVI does not have a consistent effect on recovery time, suggesting no systematic disparities based solely on socioeconomic characteristics.

Median income, representing household-level wealth, is negatively correlated with recovery time, while higher county-level economic capacity (measured by GDP per capita) is associated with longer recovery; although both effects vary with outage severity.

The number of critical facilities does not show a consistent effect once other county characteristics are accounted for.

Click this link for more information: Post-Hurricane Power Outage Recovery: Examining the Influence of Social Vulnerability, Economic Activity, and Critical Facilities | IEEE Journals & Magazine | IEEE Xplore

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