GRADSHOW 2020

Effect of Building Wind-Retrofit Strategies on Socio-economic Community-Level Resilience Metrics

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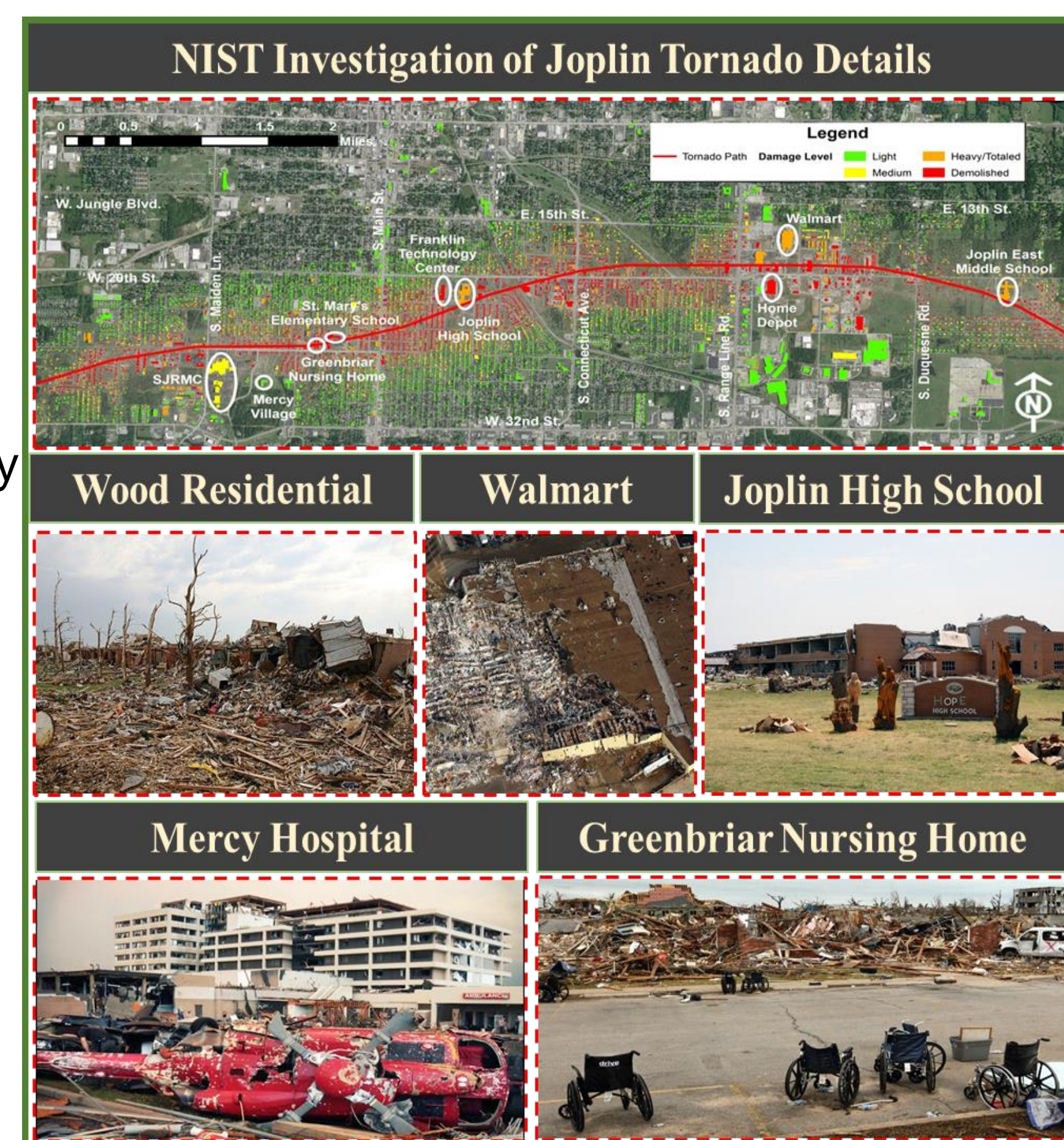**COLORADO STATE UNIVERSITY**

Introduction

- The purpose of this research is to explore the ripple effect of building functionality at different levels on the community economy and population stability.

Hazard (May 22, 2011 Tornado)
➤ EF5
➤ Fatalities: *161*, Injured: *1150*
➤ Costliest single tornado in US history
➤ US *$2.8* billion

Built Environment
➤ Buildings
➤ Electric Power Network

Socioeconomic Environment
➤ Population: *50,150*
➤ Housing units: *23,322*

NIST Investigation of Joplin Tornado Details
Wood Residential | Walmart | Joplin High School
Mercy Hospital | Greenbriar Nursing Home

Building Wind-Retrofit Strategies

Structural elements	Selections	Retrofit strategy 1	Retrofit strategy 2	Retrofit strategy 3
Roof covering	Asphalt shingles	X	X	
	Clay tiles			X
Roof sheathing nailing pattern	8d C6/12	X		
	8d C6/6		X	X
Roof-to-wall connection type	Two 16d toenails	X		
	Two H2.5 clips		X	X

Roof covering | Roof sheathing | Connection

Overview of the Framework

Initial independent community modeling
- Physical environment
- Economic systems
- Social systems

Hazard model → Infrastructure functionality analysis ← Fragility functions

Population dislocation model ← Functionality due to damage and/or loss of electric power → Computable general equilibrium model

Resilience metrics

Population stability metrics
- Percent of population dislocation
- Population dislocation by tenure status of households

Physical service metrics
- Percent of buildings functional due to damage
- Percent of buildings functional due to damage and/or loss of electric power
- Percent of buildings accepted electric power
- Percent of residents served electric power

Economic stability metrics
- Domestic supply by sectors
- Employment
- Household income

Community Resilience Model Setup

Building Portfolio

Electric Power Network

Power Generation
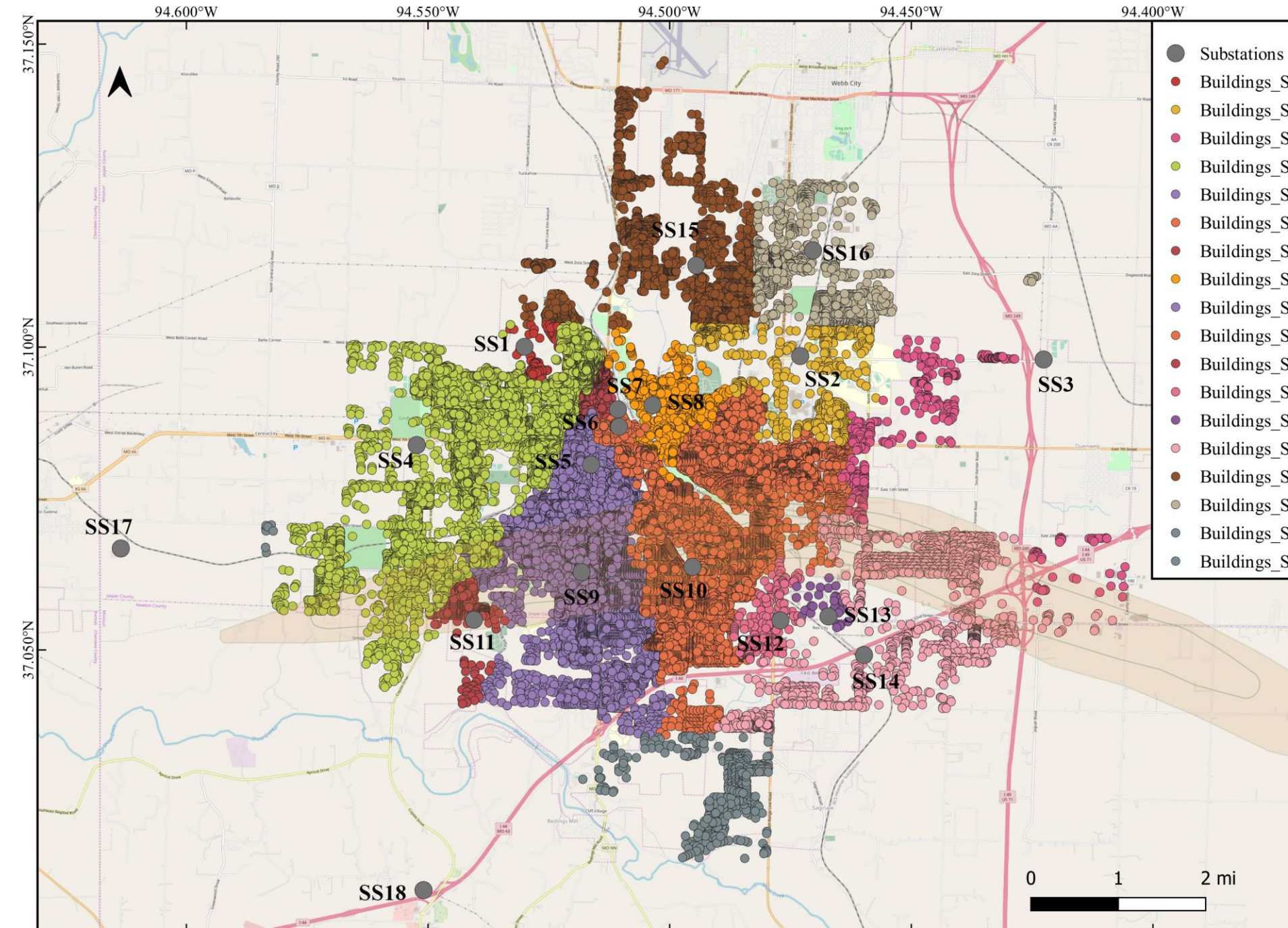Transmission
Step-up | Step-down
Distribution to homes
Factories and Buildings

Community Topology
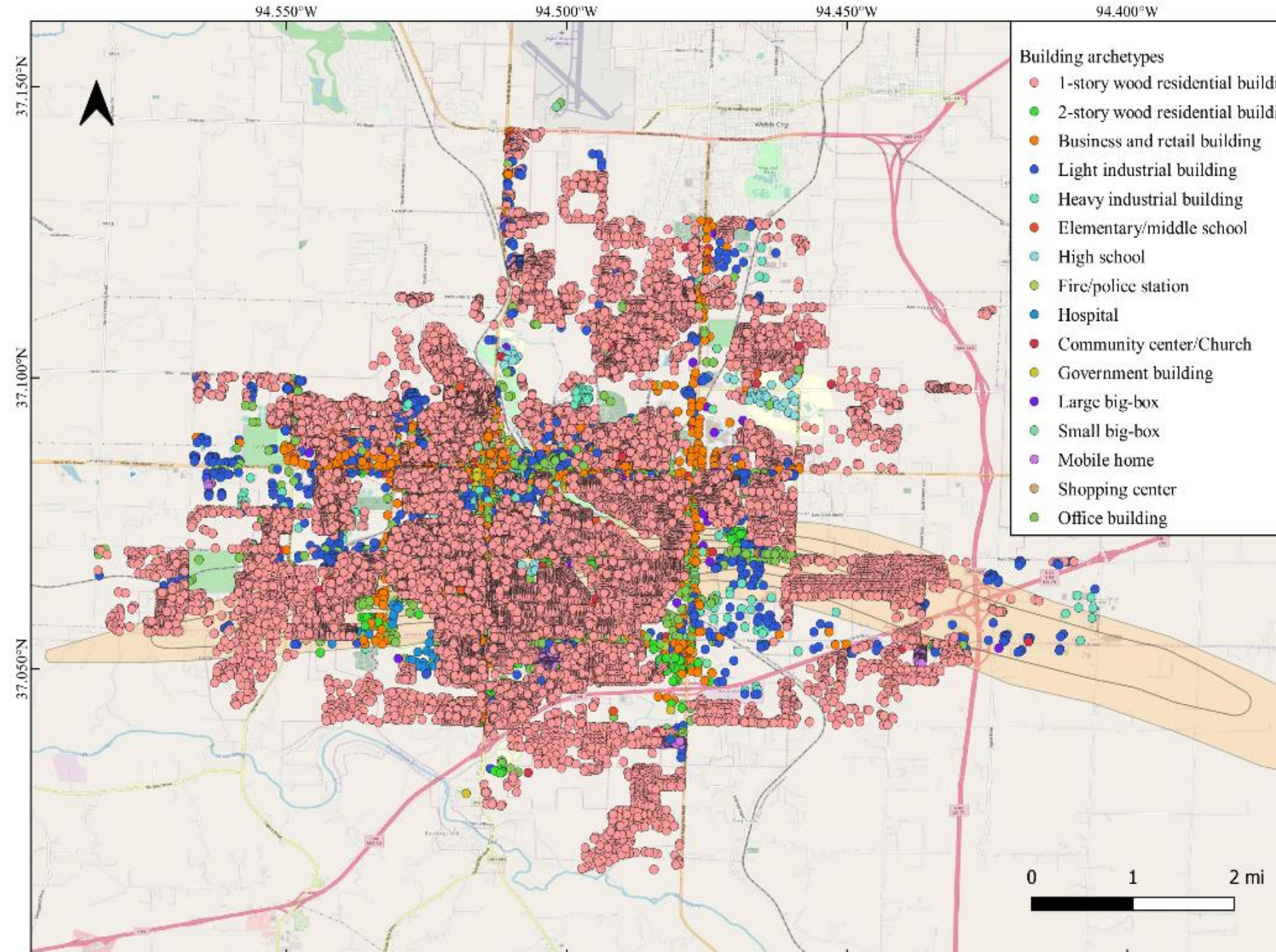
Interdependency

Results

Economic resilience metrics difference

	Retrofit strategy 1	Retrofit strategy 2	Retrofit strategy 3
Employment (unit: person)			
Goods	-358	-271	-213
Trade	-742	-563	-443
Other	-1765	-1332	-1042
Federal	-5	-4	-3
State	-13	-10	-8
City	-59	-45	-35
Total	-2942	-2224	-1744
Domestic Supply Residential (unit: millions of $)			
HS1	-61.1	-45.6	-35.5
HS2	-67.3	-49.6	-36.8
HS3	-7.7	-6.6	-6.1
Total	-136.1	-101.8	-78.3
Domestic Supply Commercial (unit: millions of $)			
Goods	-49.3	-41.5	-36.4
Trade	-42.3	-33.2	-26.9
Other	-111.1	-85.4	-68.2
Total	-202.6	-160.2	-131.5
Household Income (unit: millions of $)			
HH1	0.1	0.05	0.02
HH2	-1.0	-0.8	-0.8
HH3	-24.4	-18.2	-14.6
HH4	-100.0	-76.5	-59.6
HH5	64.9	47.9	36.7
Total	-60.5	-47.6	-38.3

Population dislocation within tornado path by housing unit characteristics

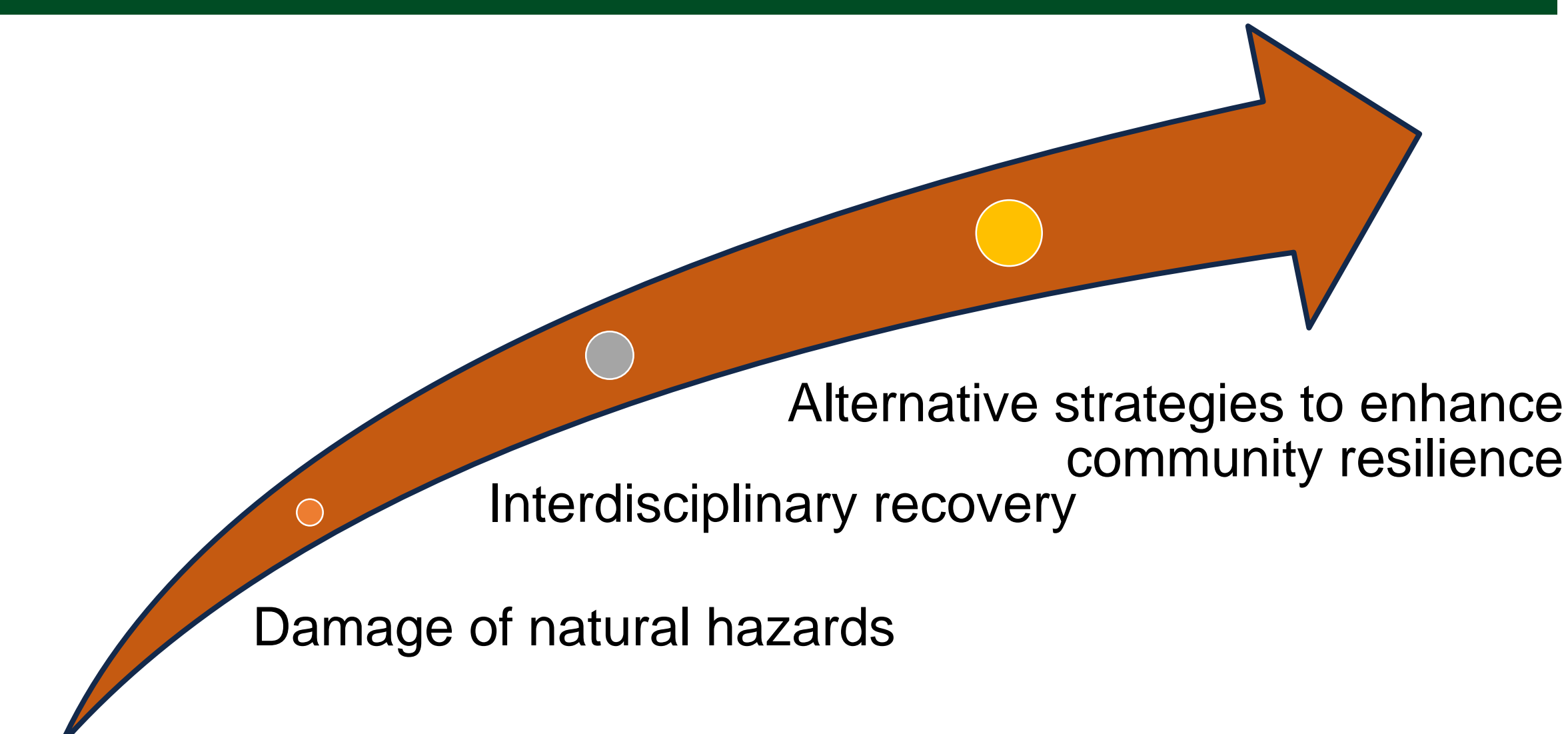| Housing Unit Characteristics	Retrofit strategy 1	Retrofit strategy 2	Retrofit strategy 3	Total population
Owner-occupied	6,349 (78.5%)	4,992 (61.7%)	4,468 (55.2%)	8,093 (100%)
Renter-occupied	5,204 (76.1%)	3,878 (56.7%)	3,458 (50.6%)	6,837 (100%)
Nursing Facilities	127 (34.1%)	127 (34.1%)	127 (34.1%)	372 (100%)
Other Group Quarters	18 (100.0%)	0 (0.0%)	0 (0.0%)	18 (100%)
In total	11,698 (76.4%)	8,997 (58.7%)	8,053 (52.6%)	15,320 (100%)

Results (Cont'd)

Percent of buildings within the tornado path functional | Percent of buildings/residents served electric power
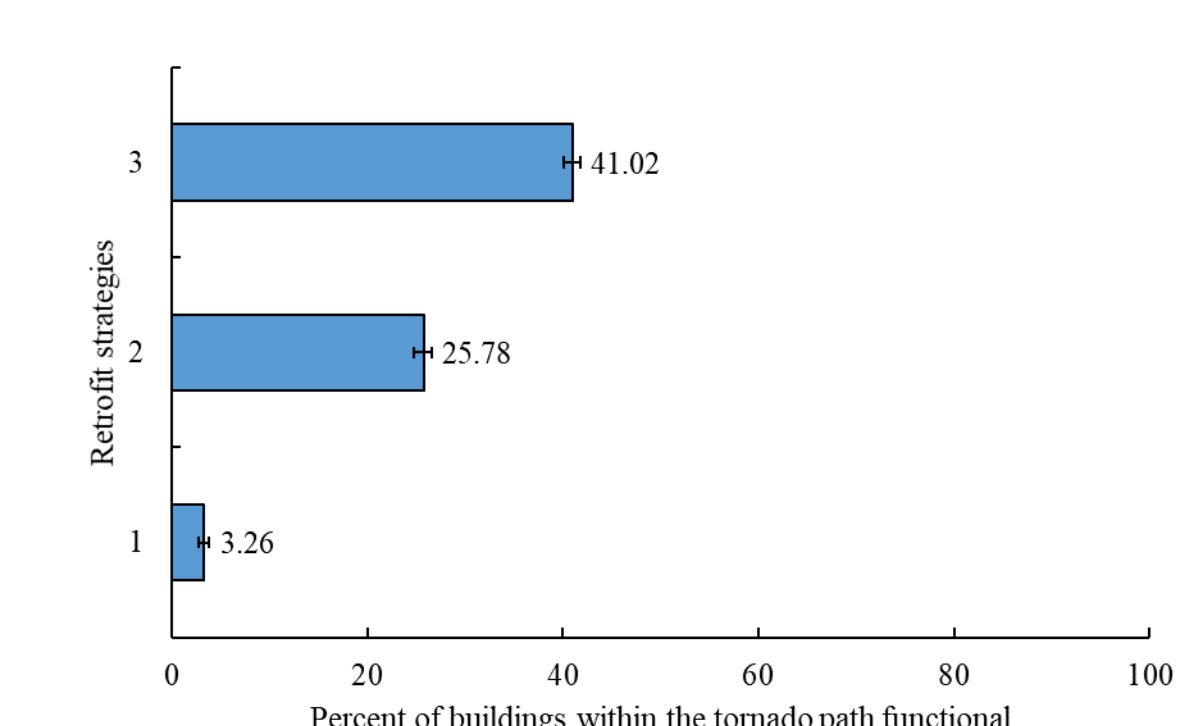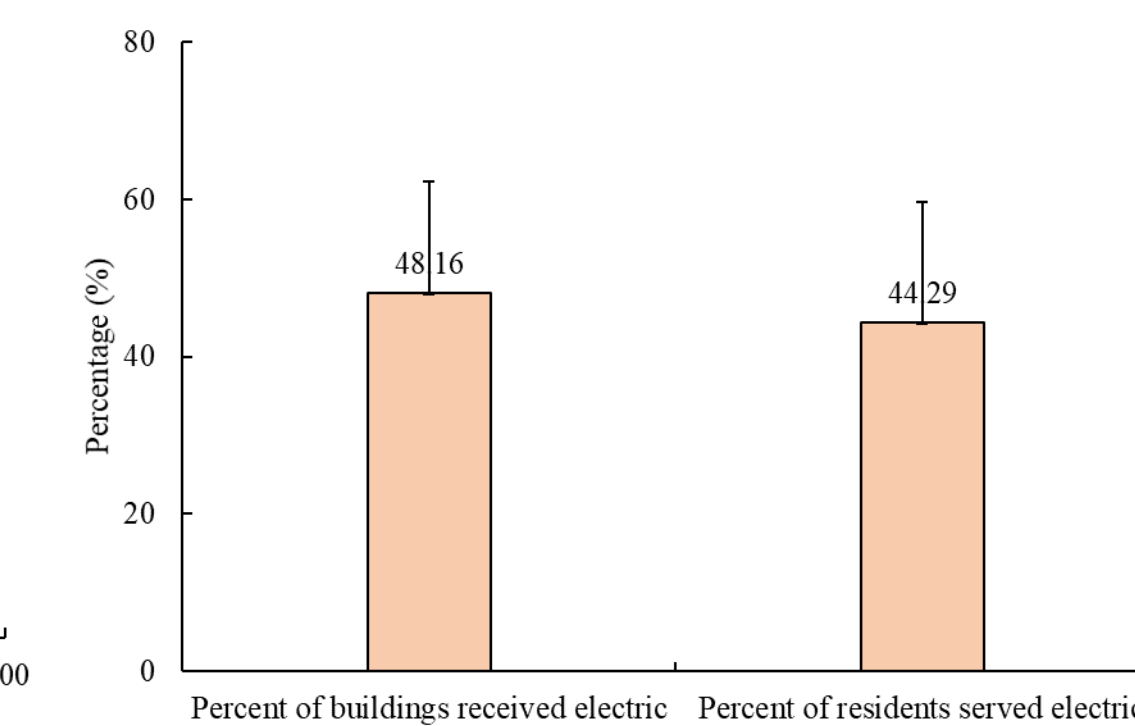
Conclusions

➤ The percentage of residential buildings within the tornado path estimated functional was 3.26%, 25.78%, and 41.02% when using retrofit strategy #1, #2, and #3.
➤ The more advanced retrofit strategy could enable structures to become more robust to the hazard, which lead to lower economic losses.
➤ Retrofit strategy #3 most significantly improved the performance of residential buildings, and then reduced the dislocated population.

Ongoing Work

Alternative strategies to enhance community resilience

Interdisciplinary recovery

Damage of natural hazards

References

➤ Wang. W(L)., van de Lindt, J.W., Rosenheim, N., Cutler, H., Hartman, B., Lee, J-S, and Calderon, D. (2020). "Effect of Residential Building Wind-Retrofit Strategies on Social and Economic Community Resilience Metrics". *Journal of Infrastructure Systems*, In Review
➤ Masoomi, Hassan, Mohammad R. Ameri, and John W. van de Lindt. "Wind performance enhancement strategies for residential wood-frame buildings." *Journal of Performance of Constructed Facilities* 32, no. 3 (2018): 04018024.

Acknowledgements