SIMULATION FRAMEWORKS FOR ASSESSING COMMUNITY RESILIENCE UNDER NATURAL HAZARDS

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1. Research Motivation

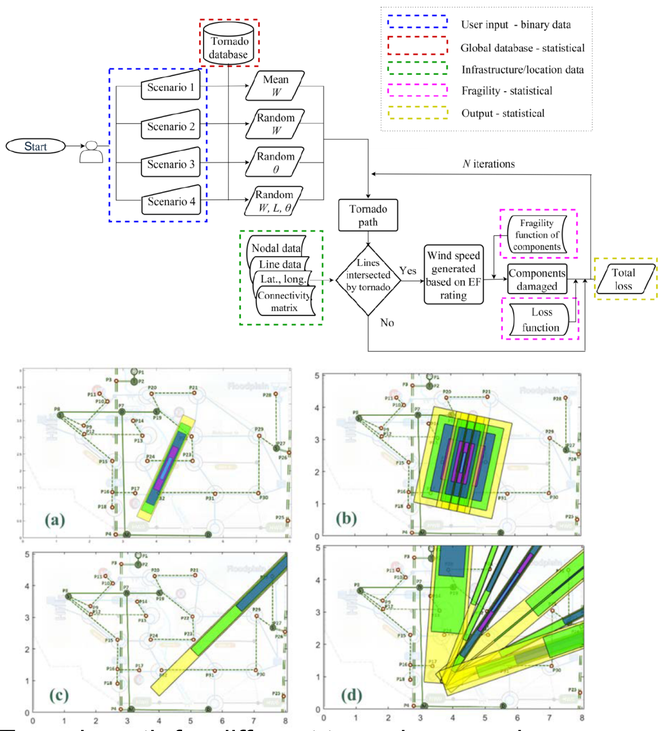
Natural disasters cost the U.S. a record of $306 billion in 2017 according to the National Oceanic and Atmospheric Administration (NOAA). Advances in computer systems have allowed engineers to statistically predict critical links and nodes in various infrastructure networks by modeling networks at the micro and macro scale. These computing tools have the potential to simulate city and community scale dynamics near real-time. Two modelling frameworks for assessing community resilience under natural hazards were explored.

The first framework is a Monte Carlo simulation used to understand the impacts of tornados on electrical power networks and telecommunication networks in Centerville. Centerville is a virtual community that was originally modeled by the Center for Risk-Based Community Resilience Planning at Colorado State University. Emphasis is placed on recovery of the wired telecommunication network.

The second type of framework is an Agent Based Model (ABM), and it has the capacity to analyze multifaceted community scale resilience from individual agent simulations. Macro-scale natural hazard events such as inundations impact the weights of edges on a graph network. Road closures and reduction in capacities are examples of influences on the weights or removal of edges which can affect the travel time, speed, and route of agents in the transportation model.

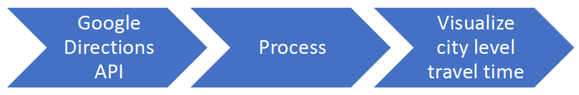
2. Framework Methodology

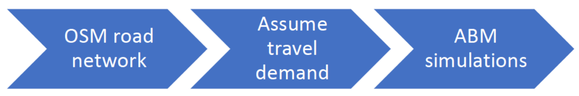
Monte Carlo Simulation

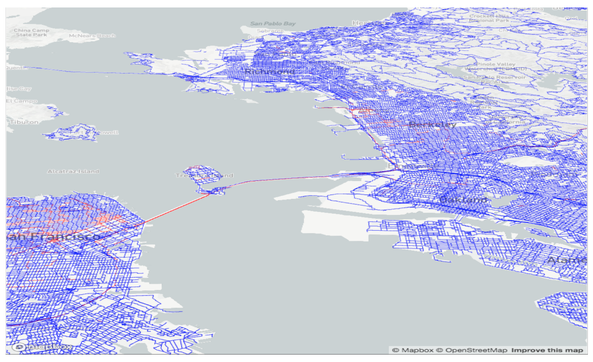


Tornado path for different tornado scenarios: (a) scenario 1, (b) scenario 2, (c) scenario 3, (b) and (d) scenario 4

Agent Based Model



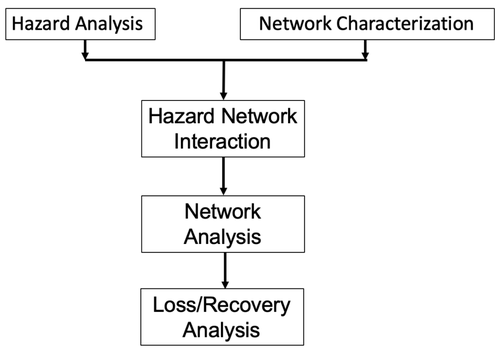




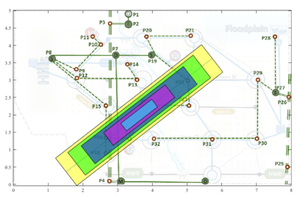
Link speed results of 40,000 agents in ABM for the Bay Area.

3. Simulations

Monte Carlo Performance Analysis



Hazard-network interaction is the intersection of tornado path and telecommunications layout and wind pressure on the components. Network analysis comprises of component and connectivity. Finally loss analysis converts the damage into actual loss and recovery times using the loss/recovery functions.



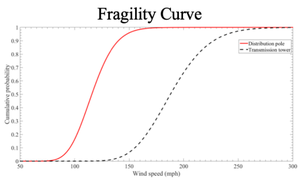
Loss Function

Component	Distribution	Parameters	
		Mean	COV
Transmission towers	Lognormal	$0.4M	0.10
Distribution poles	Lognormal	$1,435	0.10

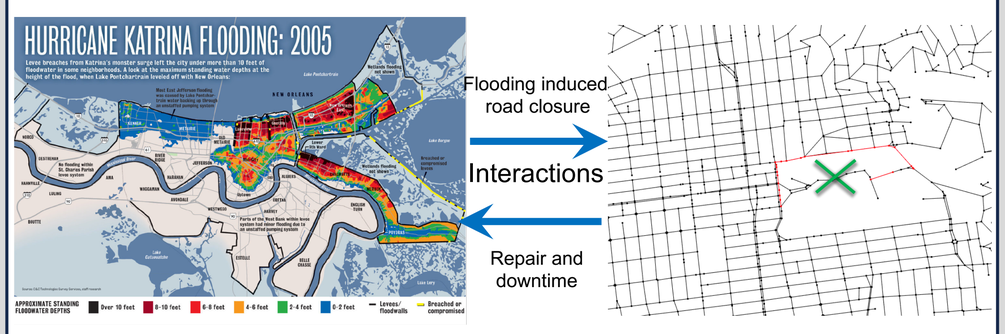
Sample Result

Nodes Affected	Path to Node 24		Path to Node 32	
	Mean	COV	Mean	COV
Number of poles damaged	14	0.16	2	0.17
Length of line damaged (miles)	0.35	0.16	0.05	0.17
Cost of replacement	$19,761	0.19	$2,787	0.21

Fragility Curve



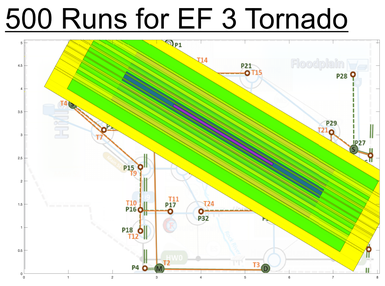
Agent Based Model Analysis



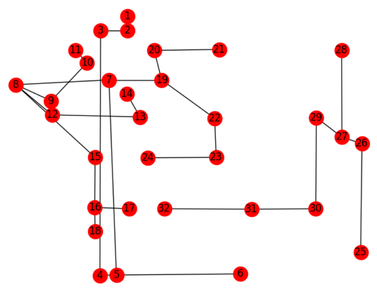
ABM to understand the impact of intense flooding events on New Orleans, LA's transportation network.

4. Results

500 Runs for EF 3 Tornado

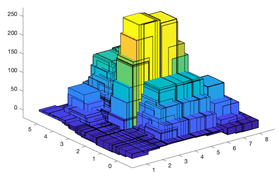


PageRank of Telecommunication Nodes



1: 0.019849,
2: 0.035676,
3: 0.033214,
4: 0.031447,
5: 0.044622,
6: 0.0173310,
7: 0.0417882,
8: 0.0560571,
9: 0.031190,
10: 0.03432,
11: 0.019277,
12: 0.031190,
13: 0.0343280,
14: 0.0192774,

Recovery Time Frequency Analysis



TEL Recovery Time (hours)**	Std. Dev. Repair Time	95% Conf Interval	COV
0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00
0.00	0.34	0.03	0.00
0.00	0.34	0.71	0.00
0.00	0.34	0.71	0.00
0.00	0.57	0.74	0.00
0.00	0.57	1.19	0.00
8.28	11.54	2.58	0.00
33.38	31.46	39.64	1.90
25.09	37.93	113.11	0.76
3.74	10.76	77.21	0.00
13.28	40.12	29.02	5.36
9.54	53.62	99.31	2.81
0.00	7.76	108.21	0.00
0.00	7.76	16.49	0.00
0.00	7.76	16.49	0.00
37.38	7.76	16.49	0.00
76.79	40.25	90.27	0.54
80.10	47.84	159.34	0.61

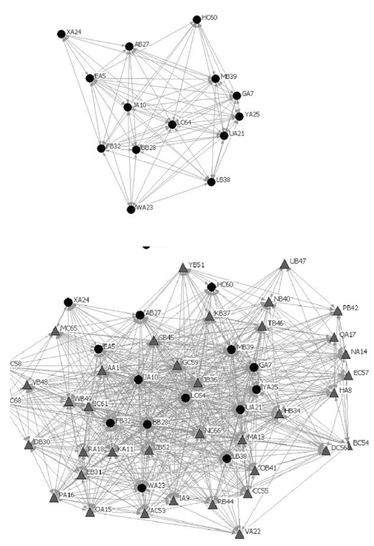
Examining New Orleans Transportation Network

City of New Orleans road network

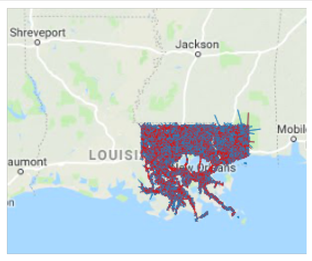
1 mile x 1 mile road network of Downtown New Orleans

5. Future Work

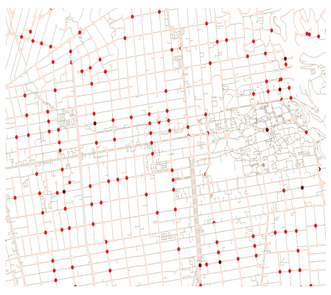
Influence of Governing Social Networks



50,000 Agents Simulated on Southeastern Louisiana Road Network.



Pagerank of Traffic Nodes



Acknowledgements

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