Analysis of Disrupted Transportation Network in Multi-Hazard Scenario

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Final Presentation

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Overview

- Introduction

- Background
  - Community Resilience
  - Methodology of Community Resilience
- Networks
- Transportation Network

Overview

- Introduction
- Objective

- Find Research Gap
- Fulfilling the Research Gap

Overview

- Introduction
- Objective
- Data

- INCORE
- DATASET
- Important Packages
- Visualizations of Dataset

Overview

- Introduction
- Objective
- Data
- Methodology

- Techniques
  - All pathways
  - Independent Pathway (IPW)
  - Example of IPW
- Procedure
  - Maximum Flow Optimization
  - Methods used to Implement

Overview

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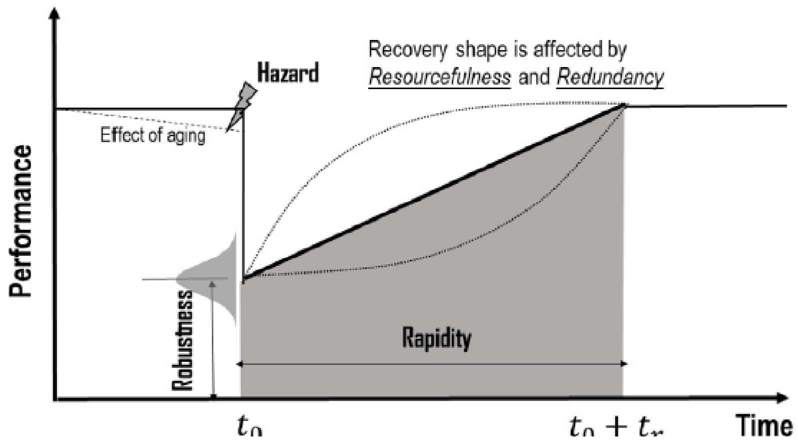
- Objective
- Data
- Methodology
- Results
- Conclusion
- References

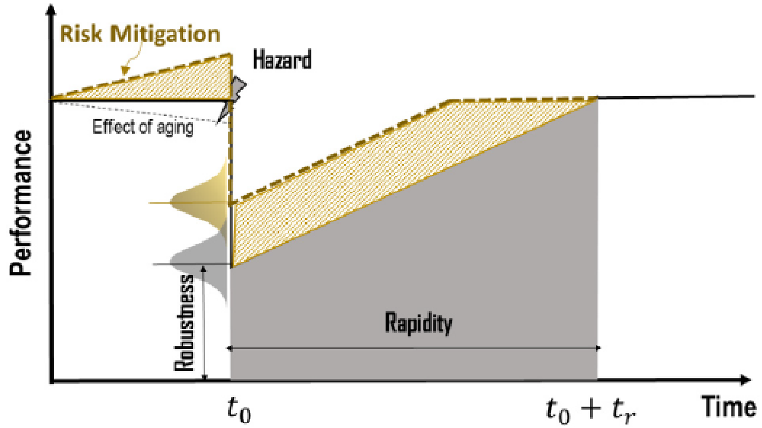
Introduction: Community Resilience

- What is Community Resilience?

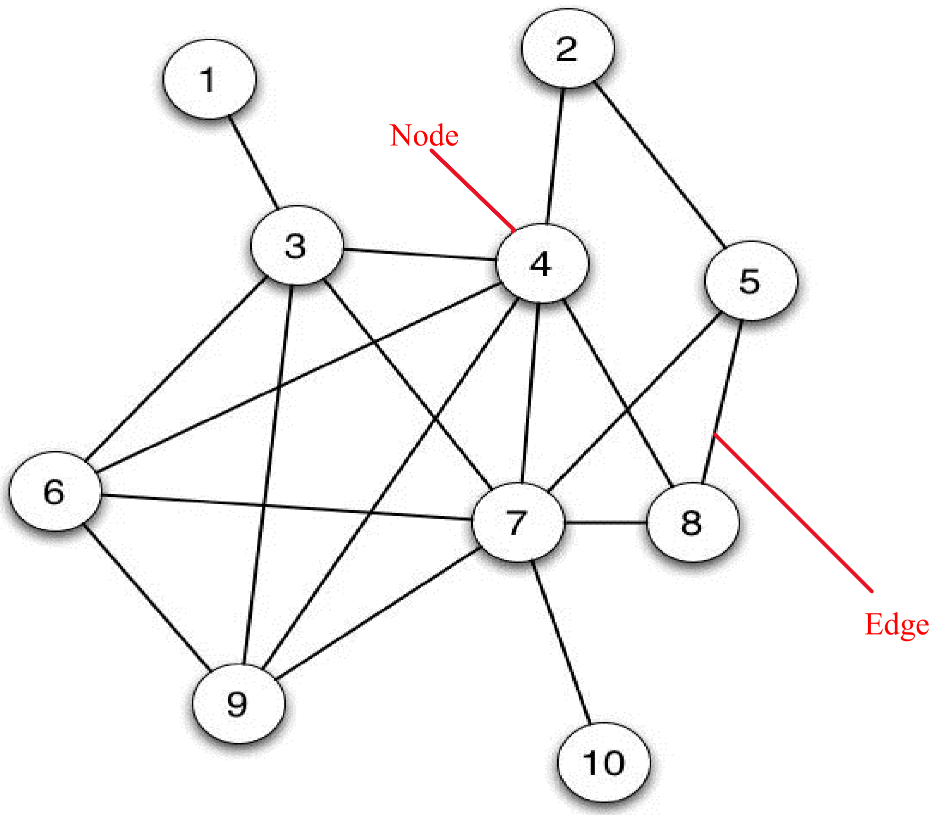
Introduction: Community Resilience

- What is Community Resilience?
- Methodologies of Community Resilience
  - Robustness
  - Rapidity
  - Redundancy
  - Resourcefulness





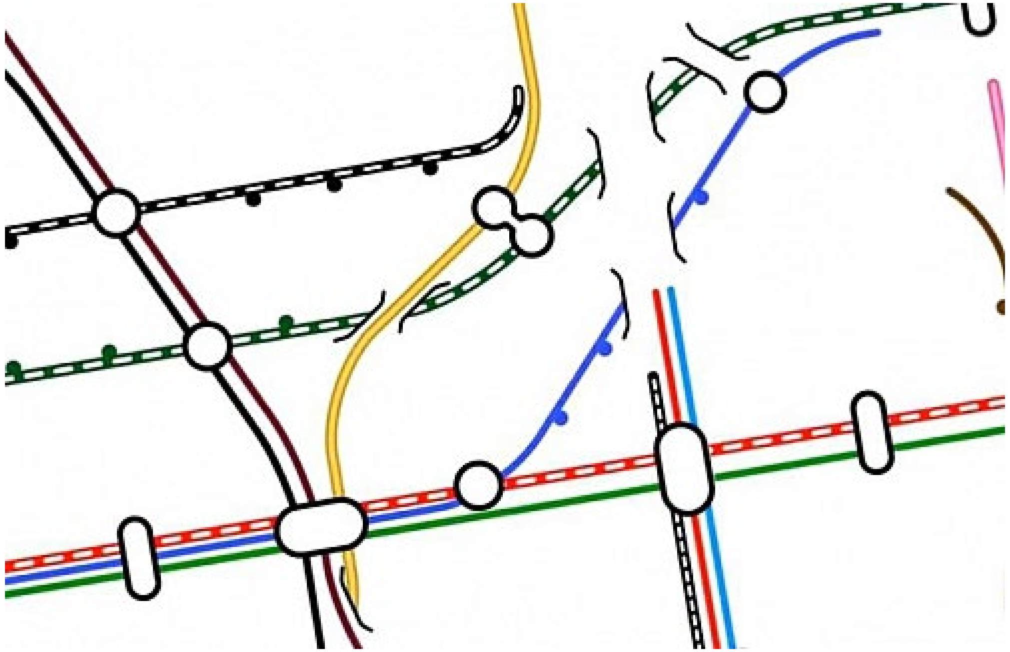
Introduction: Network



Introduction: Transportation Network

- What is Transportation Network?
- Types of Transportation Networks
  - Air Networks
  - Road Networks
  - Rail Networks

- Transportation Network for Community Resilience
  - Earthquakes
  - Severe Windstorms
  - Flooding
  - Terrorism
- Importance of Transportation Network



Objective

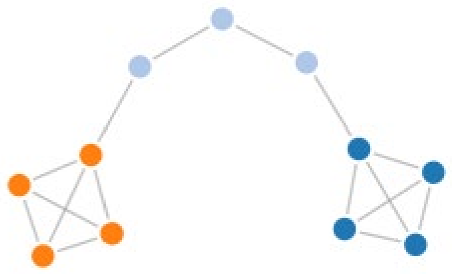
- The Goal of this project is to create an efficient way of computing the independent pathways (IPW) to work as a fitness function for a metaheuristic to support a prescriptive analytics framework
  - Network Analysis on Seaside Testbed

Objective

GeoPandas

NetworkX
Network Analysis in Python

momepy
Urban Morphology Measuring Toolkit



Data: INCORE

- Interdependent Networked Community Resilience Modeling Environment (INCORE) platform

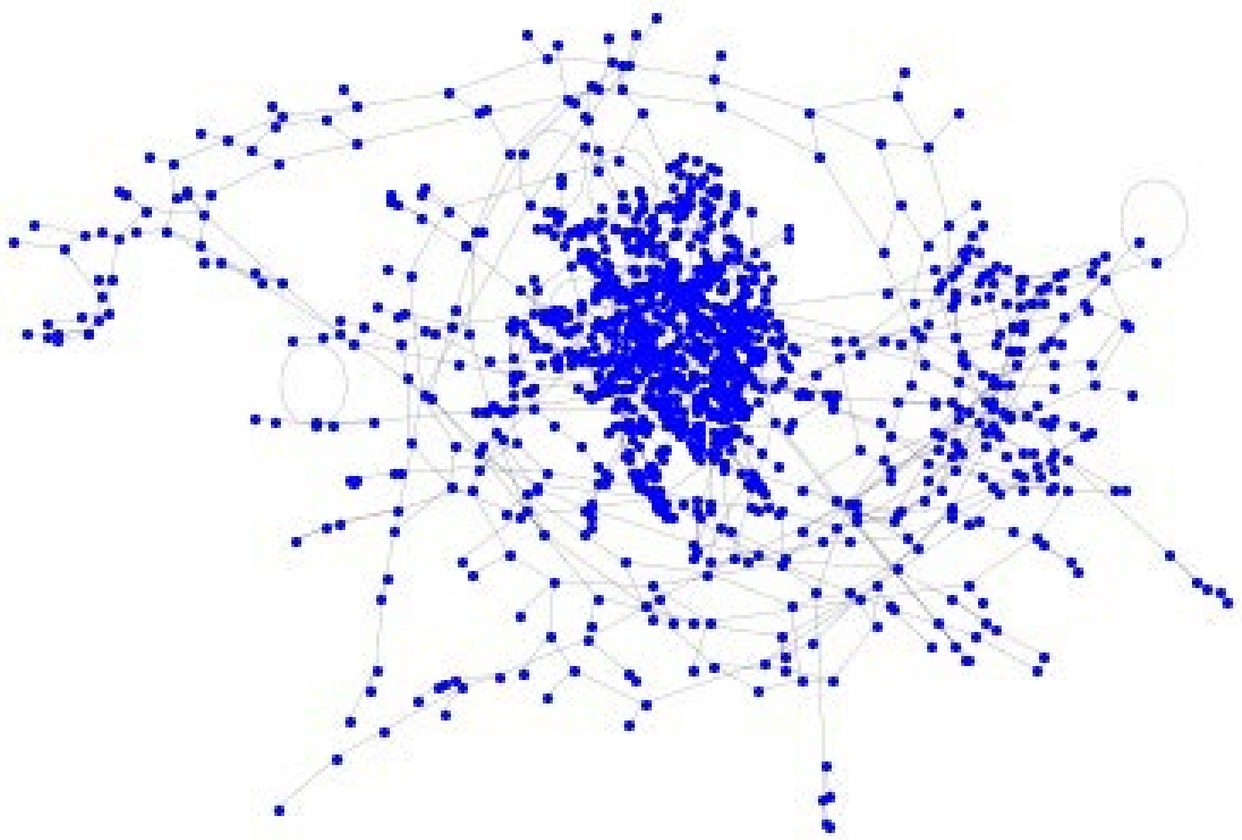
Data: Original Dataset

- Interdependent Networked Community Resilience Modeling Environment (INCORE) platform
- Dataset from the Seaside testbed
  - 585 rows with 14 features

	FID	Link_ID	Shape *	id	highway	start_x	end_x	start_y	end_y	Length	start_xy	end_xy	Start_node	End_node
0	0	1	Polyline	246115483	residential	444201	444076	1565732	1565611	174.195189	4442011565732	4440761565611	284	272
1	1	2	Polyline	5309249	service	445331	445197	1568639	1568646	134.623826	4453311568639	4451971568646	364	350
2	2	3	Polyline	5309445	service	444382	444698	1563465	1563391	324.748323	4443821563465	4446981563391	300	316
3	3	4	Polyline	5309941	service	443375	442992	1565987	1566002	383.083680	4433751565987	4429921566002	240	212
4	4	5	Polyline	5312662	living_street	444187	444766	1560893	1560714	629.169338	4441871560893	4447661560714	280	325
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
580	580	581	Polyline	246250773	service	447326	447522	1569147	1569196	202.513348	4473261569147	4475221569196	421	424
581	581	582	Polyline	246251063	service	447667	447388	1568878	1567941	984.065756	4476671568878	4473881567941	425	423
582	582	583	Polyline	246251063	service	447388	447280	1567941	1568972	1155.337296	4473881567941	4472801568972	423	420
583	583	584	Polyline	246251063	service	447280	447667	1568972	1568878	402.781054	4472801568972	4476671568878	420	425
584	584	585	Polyline	246250787	service	446577	447280	1567398	1568972	1829.617221	4465771567398	4472801568972	408	420

585 rows × 14 columns

Data: Original Dataset



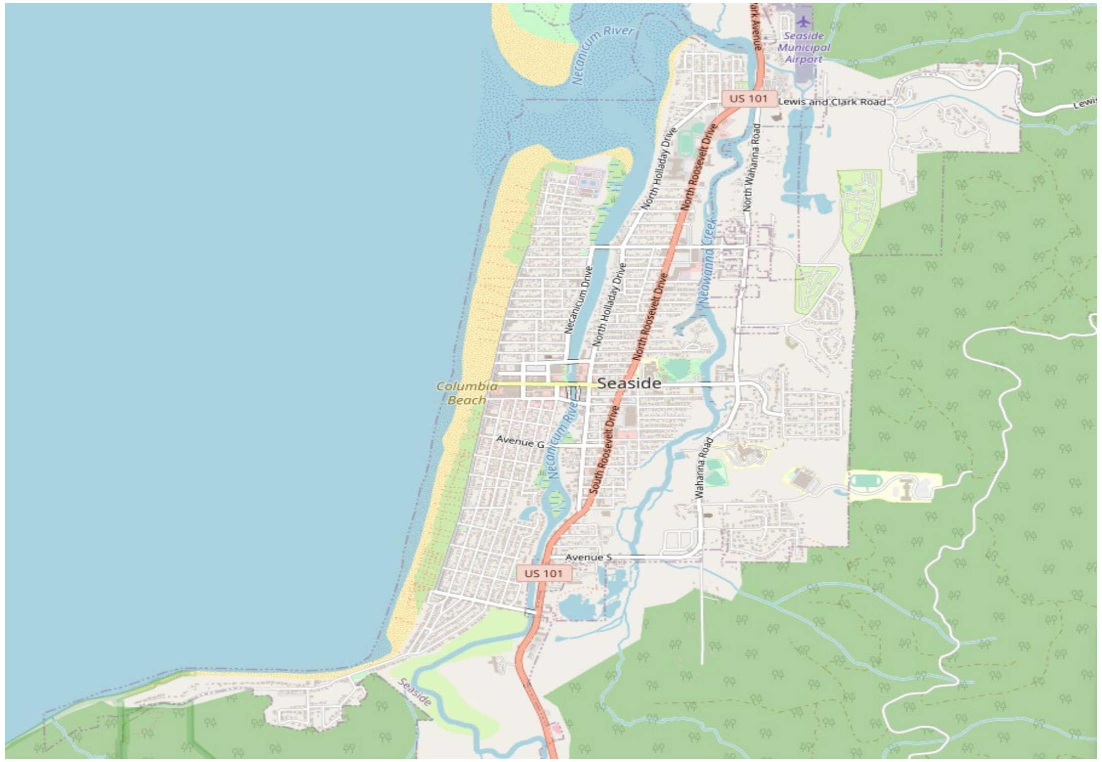
Network of Seaside Dataset based on Geographic locations using NetworkX

Data: Geopandas

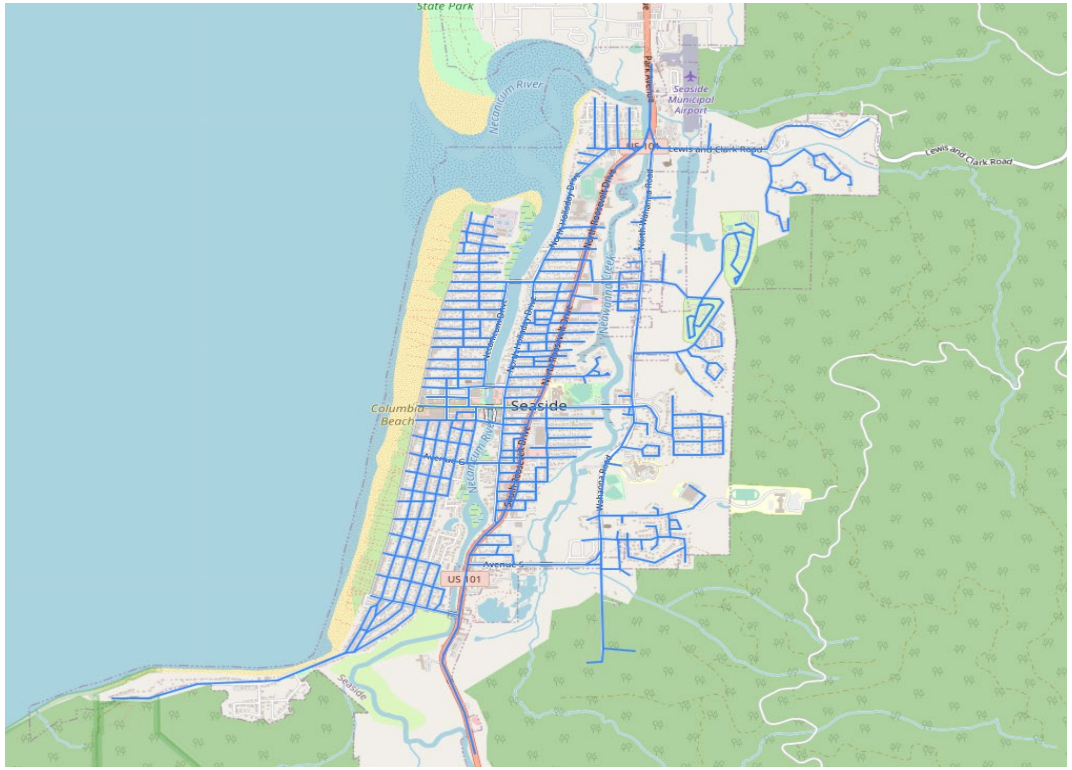
	id	highway	start_x	end_x	start_y	end_y	Length	start_xy	end_xy	Start_node	End_node	Link_ID	geometry
0	246115483	residential	444201	444076	1565732	1565611	174.195189	4442011565732	4440761565611	284	272	1	LINESTRING (444202.129 1565735.383, 444076.694...
1	5309249	service	445331	445197	1568639	1568646	134.623826	4453311568639	4451971568646	364	350	2	LINESTRING (445331.908 1568642.190, 445197.463...
2	5309445	service	444382	444698	1563465	1563391	324.748323	4443821563465	4446981563391	300	316	3	LINESTRING (444382.459 1563467.782, 444698.695...
3	5309941	service	443375	442992	1565987	1566002	383.083680	4433751565987	4429921566002	240	212	4	LINESTRING (443375.774 1565990.045, 442993.006...
4	5312662	living_street	444187	444766	1560893	1560714	629.169338	4441871560893	4447661560714	280	325	5	LINESTRING (444188.216 1560895.983, 444564.392...
...	...	...	...	...	...	...	...	...	...	...	...	...	...
580	246250773	service	447326	447522	1569147	1569196	202.513348	4473261569147	4475221569196	421	424	581	LINESTRING (447326.833 1569150.054, 447523.257...
581	246251063	service	447667	447388	1568878	1567941	984.065756	4476671568878	4473881567941	425	423	582	LINESTRING (447667.835 1568881.531, 447555.138...
582	246251063	service	447388	447280	1567941	1568972	1155.337296	4473881567941	4472801568972	423	420	583	LINESTRING (447388.803 1567943.769, 447188.174...
583	246251063	service	447280	447667	1568972	1568878	402.781054	4472801568972	4476671568878	420	425	584	LINESTRING (447280.905 1568975.071, 447420.290...
584	246250787	service	446577	447280	1567398	1568972	1829.617221	4465771567398	4472801568972	408	420	585	LINESTRING (446578.068 1567401.421, 446985.843...

585 rows × 13 columns

Data: Geopandas

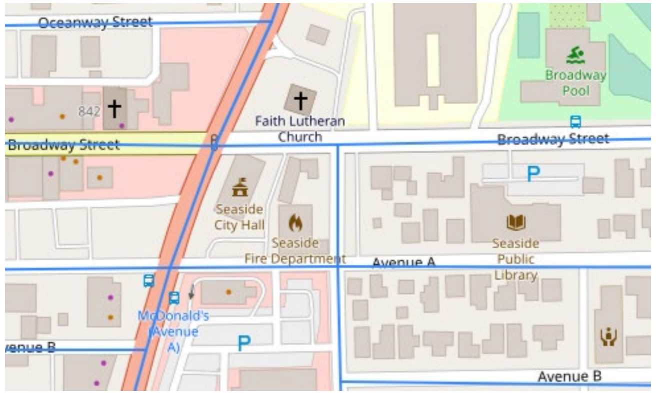


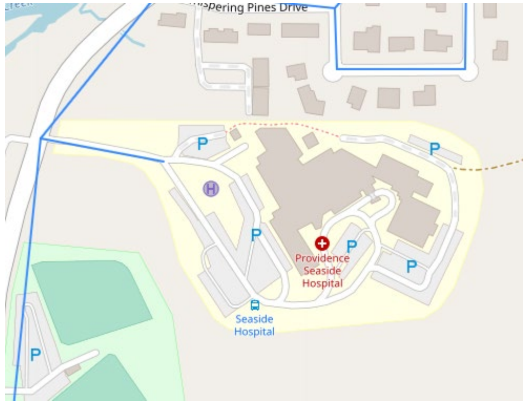
Original Map of the Seaside Testbed without any Implementation

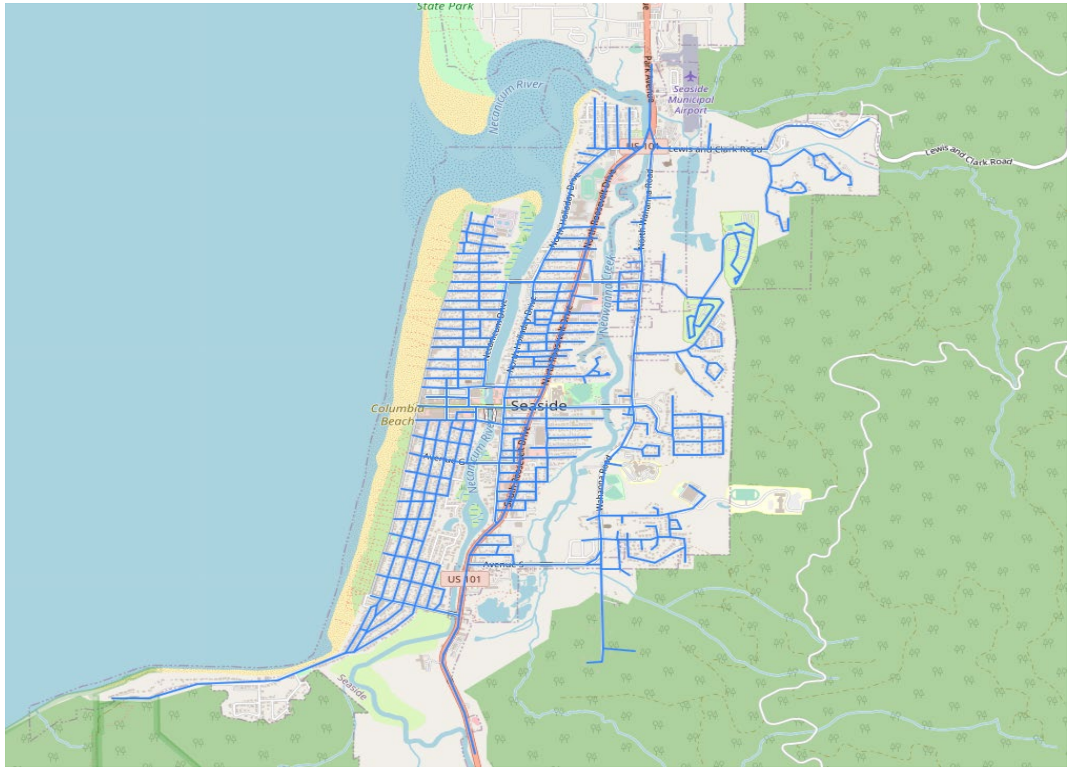


Implementation of Linestrings on Seaside Map using GeoPandas

Data: Geopandas



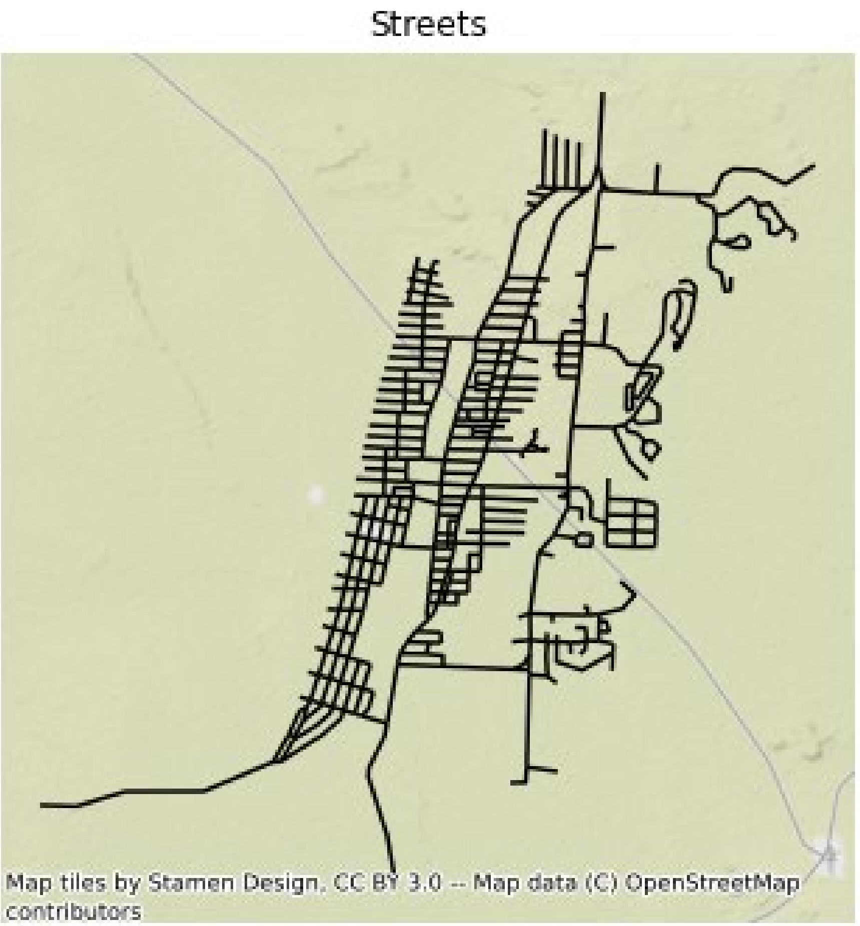


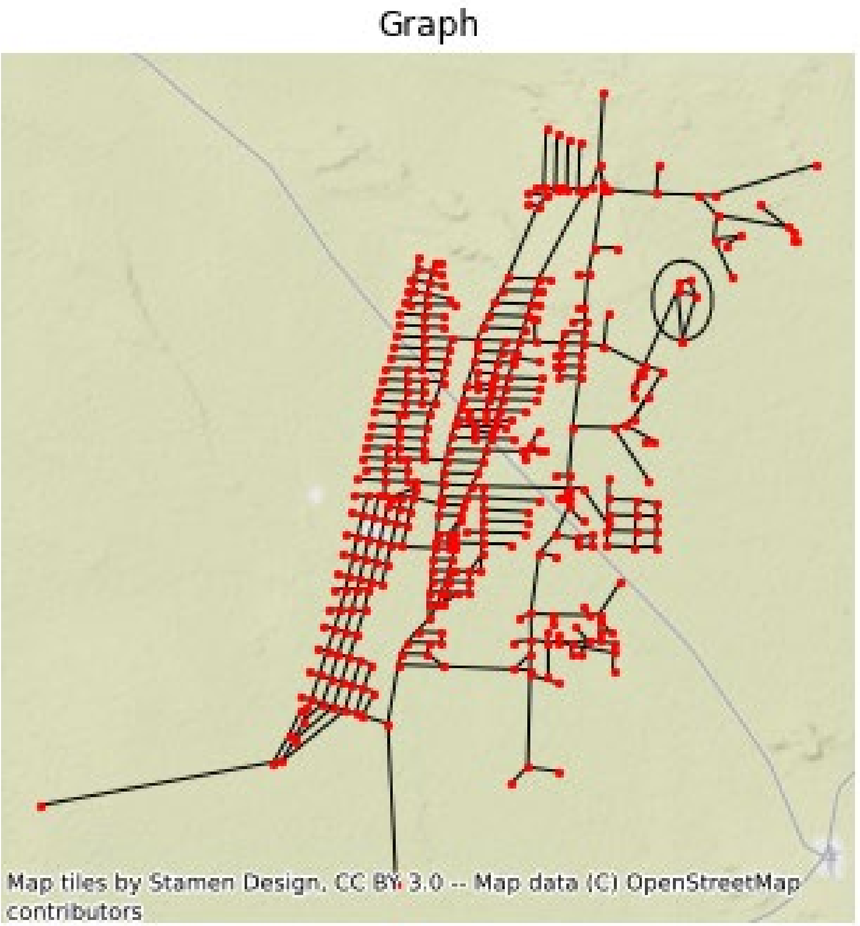


Representation of Emergency Locations in the Seaside Testbed using GeoPandas

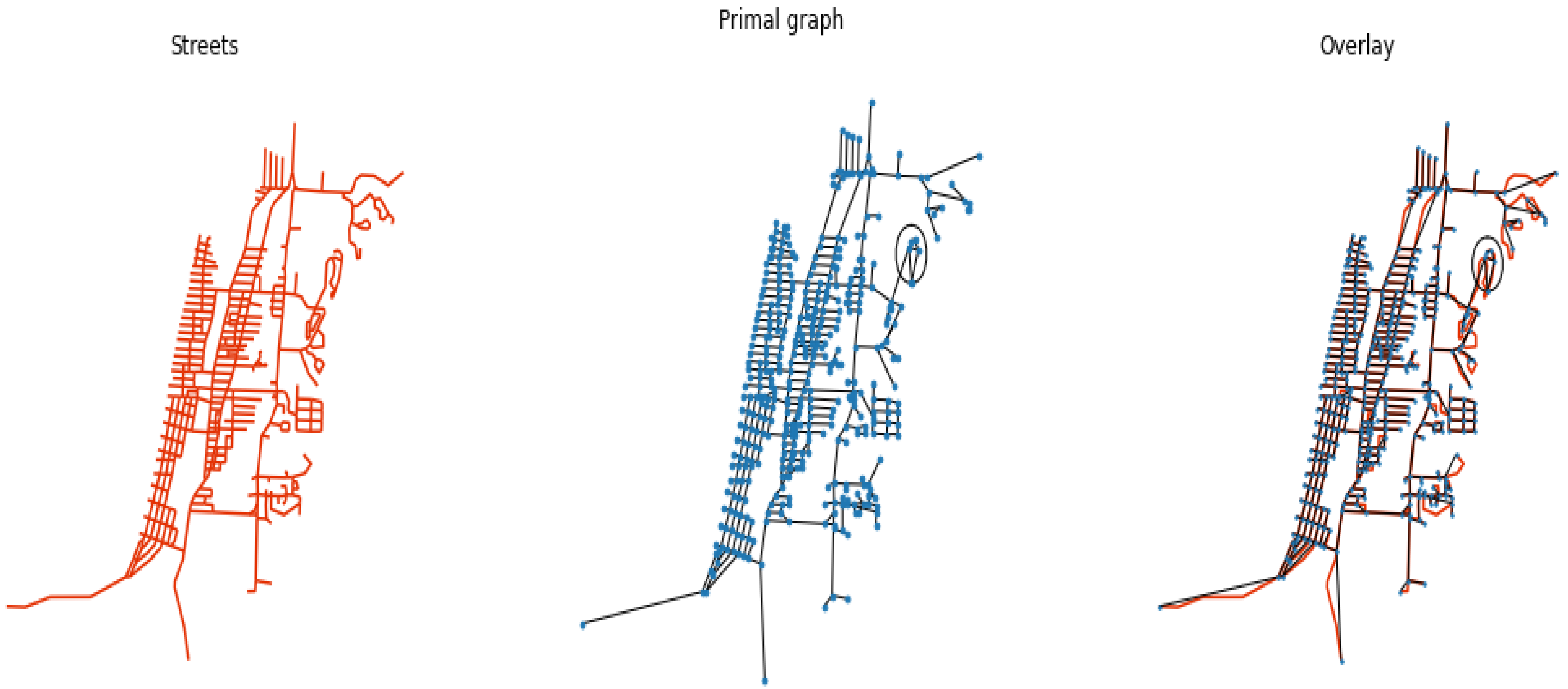
Implementation of Linestrings on Seaside Map using GeoPandas

Data: Momepy


Streets
Map tiles by Stamen Design, CC BY 3.0 -- Map data (C) OpenStreetMap contributors

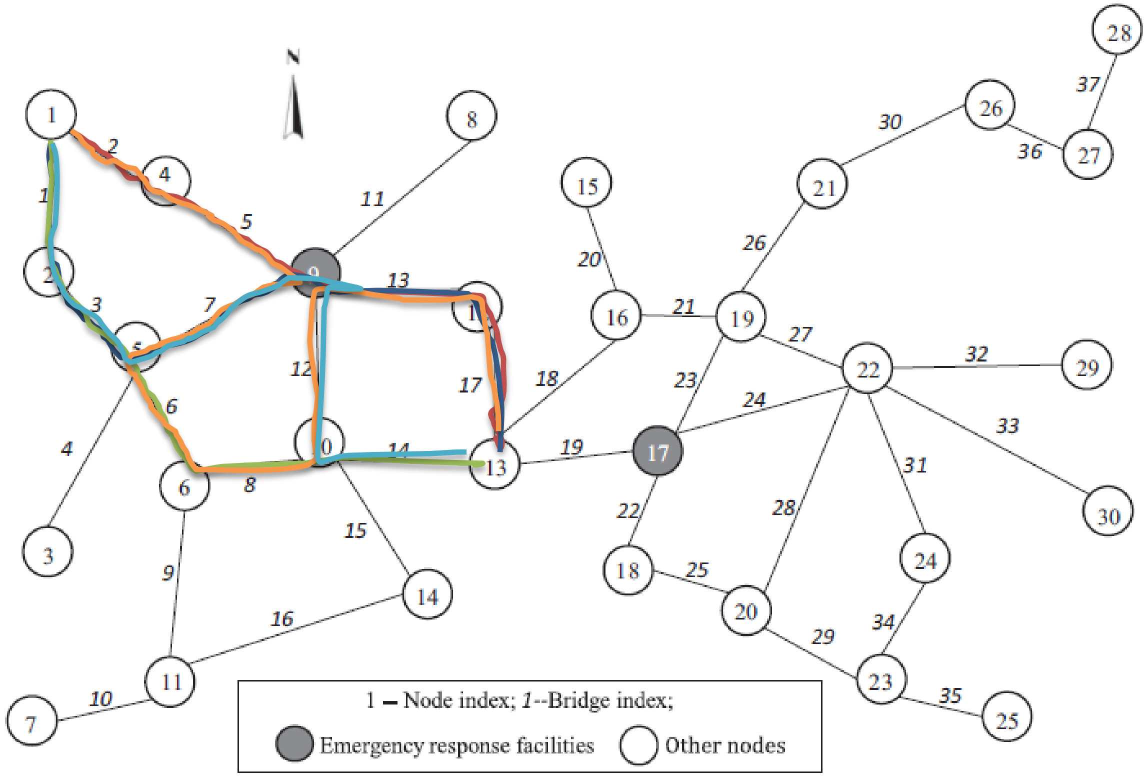

Graph
Map tiles by Stamen Design, CC BY 3.0 -- Map data (C) OpenStreetMap contributors

Data: Momepy



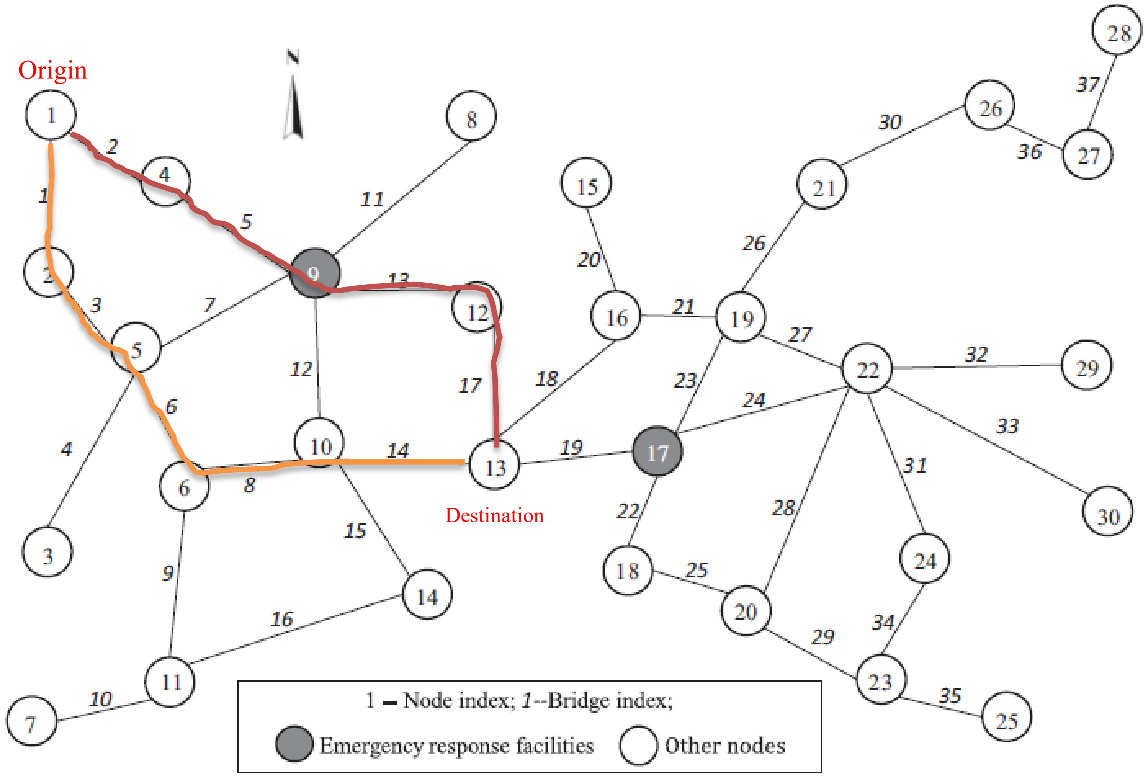
Methodology: Techniques

- Background of the Research: Resilience based risk mitigation for road networks
  - Weili Zhang and Naiyu Wang (2016)
- All Pathways (APW)



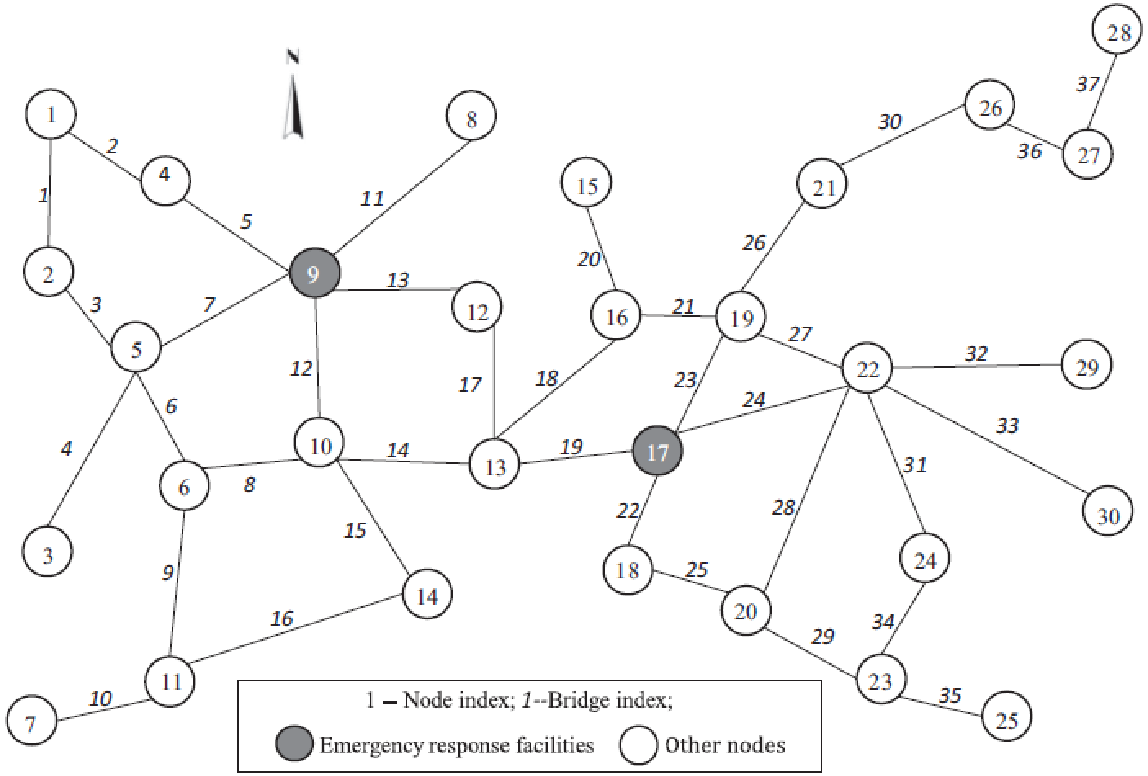
Methodology: Techniques

- Background of the Research: Resilience based risk mitigation for road networks
  - Weili Zhang and Naiyu Wang
  - 2016
- All Pathways (APW)
- Independent Pathways (IPW)



Methodology: Techniques

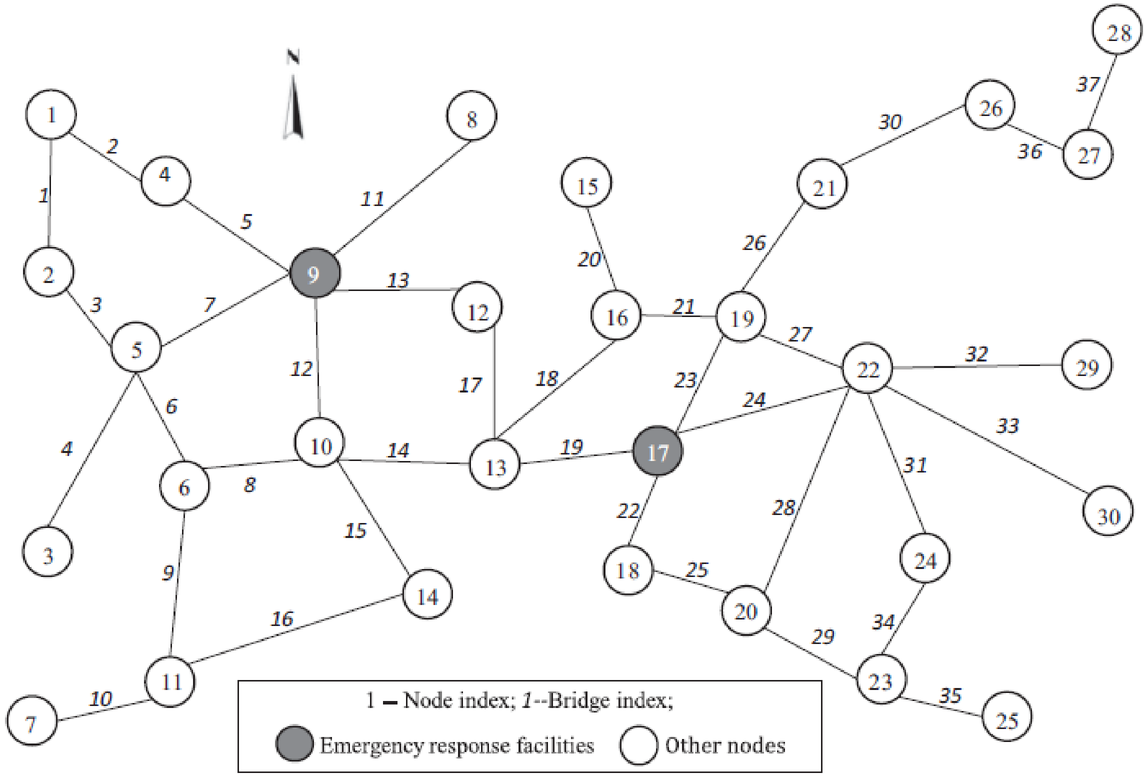
- Background of the Research: Resilience based risk mitigation for road networks
  - Weili Zhang and Naiyu Wang
  - 2016
- All Pathways (APW)
- Independent Pathways (IPW)
- Dijkstra Algorithm
- ShortestPath Method
- On 30 Nodes and 35 Edges
- 30 minutes execution time
- Virtual Data



Methodology: Techniques

- Limitations of this Technique:
  - Inefficient Approach
  - Too Long Time
  - Real Data is much larger and complicated

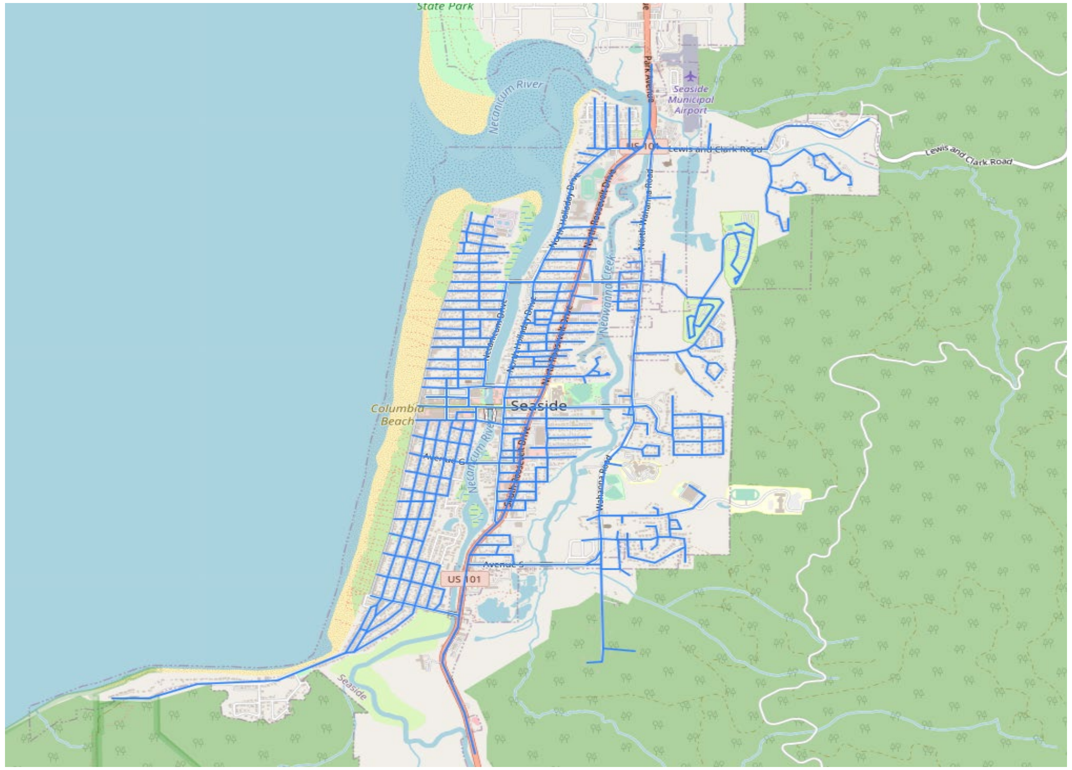
- My Approach
  - Independent Pathways (IPW)
  - Maximum Flow algorithm
  - On Real Data



Methodology: Procedure

- Maximum Flow
- Different algorithm
  - Preflow_push
  - Shortest Augmenting Path
  - Dinic's Algorithm
  - Edmond Karp Algorithm

- Seaside Testbed
  - 438 nodes
  - 583 edges

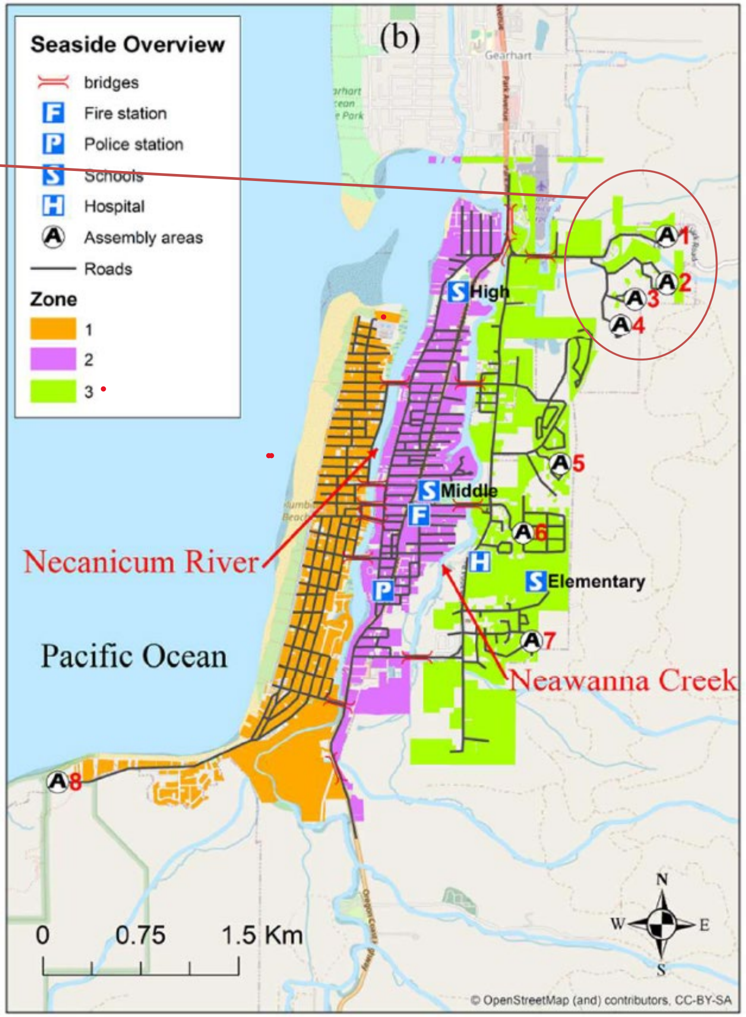


Methodology: Procedure

Maximum Flow Algorithm Used	Average all pairs maximum Flow = (IPW)	Total Time is taken to execute this Network (in seconds)
Max_Flow with Preflow_push	2.073661	1441.01
Shortest_augmeting Path	2.073661	1.331.25
Dinic's Algorithm	2.073661	425.06
Edmond Karp Algorithm	2.073661	366.38

Results

- Evacuation Points
  - Eight Evacuation points
- Applied Maximum
  - Edmond Karp Algorithm



- Final Result: 19.682 seconds

Results

- Original Results = Shortest Path Problem and Dijkstra algorithm
- Reproduced New results = Maximum Flow using Edmond Karp Algorithm

	Nodes	Edges	Time
Original Results	30	37	30 minutes
Reproduced New Results	438	583	366.38 seconds

- For eight evacuation points

	Evacuation Points	Time
Reproduced New Results For 8 evacuation points	8	19.683 seconds

Conclusion

- Transportation networks in community resilience are critical
- Independent Pathways (IPW) metric is introduced
- A vital measure is necessary
- The IPW efficiently measures a network's ability to execute in the face of a potential hazard
- Calculating the IPW efficiently so they can be used to support a prescriptive analytics framework for metaheuristics
- Maximum Flow is used for IPW
- Based on the results, Maximum Flow approach is quite efficient than the traditional approach
- Decision-makers can decide on the resilience strategies associated with various hazard scenarios
- Insurers and policymakers can use the approach presented to manage bridges against multiple hazards throughout their lifetimes

References

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THANK YOU!

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(BACKUP) Maximum Flow: Time Complexities

Preflow_push	**O(n2 m)**
Dinics algorithm	O(n2m)
Edmond Karp Algorithm	O(nm2)
Shortest Augmenting Path	O(n2m)