Assessing the Resilience of an Urban Transportation Network

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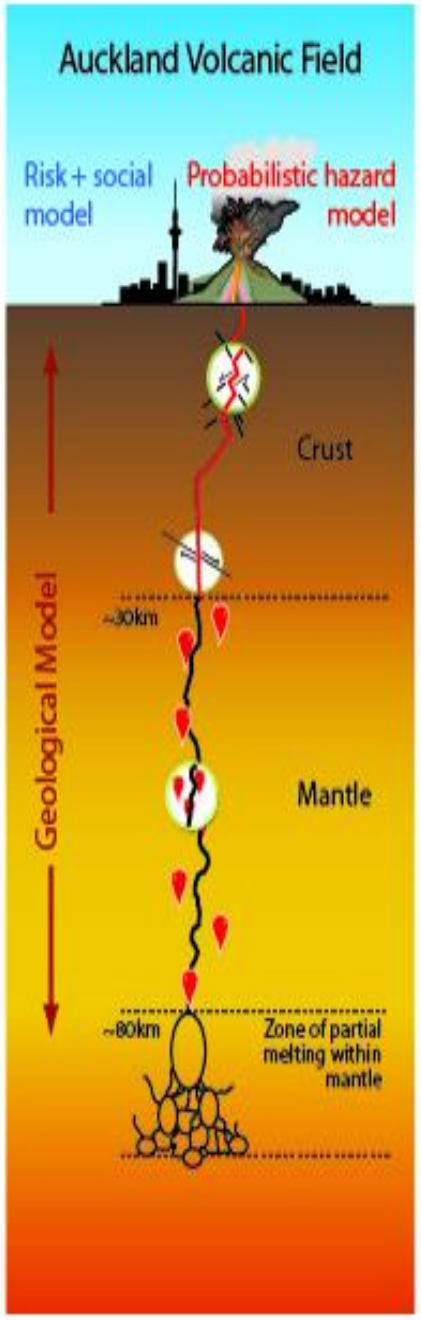
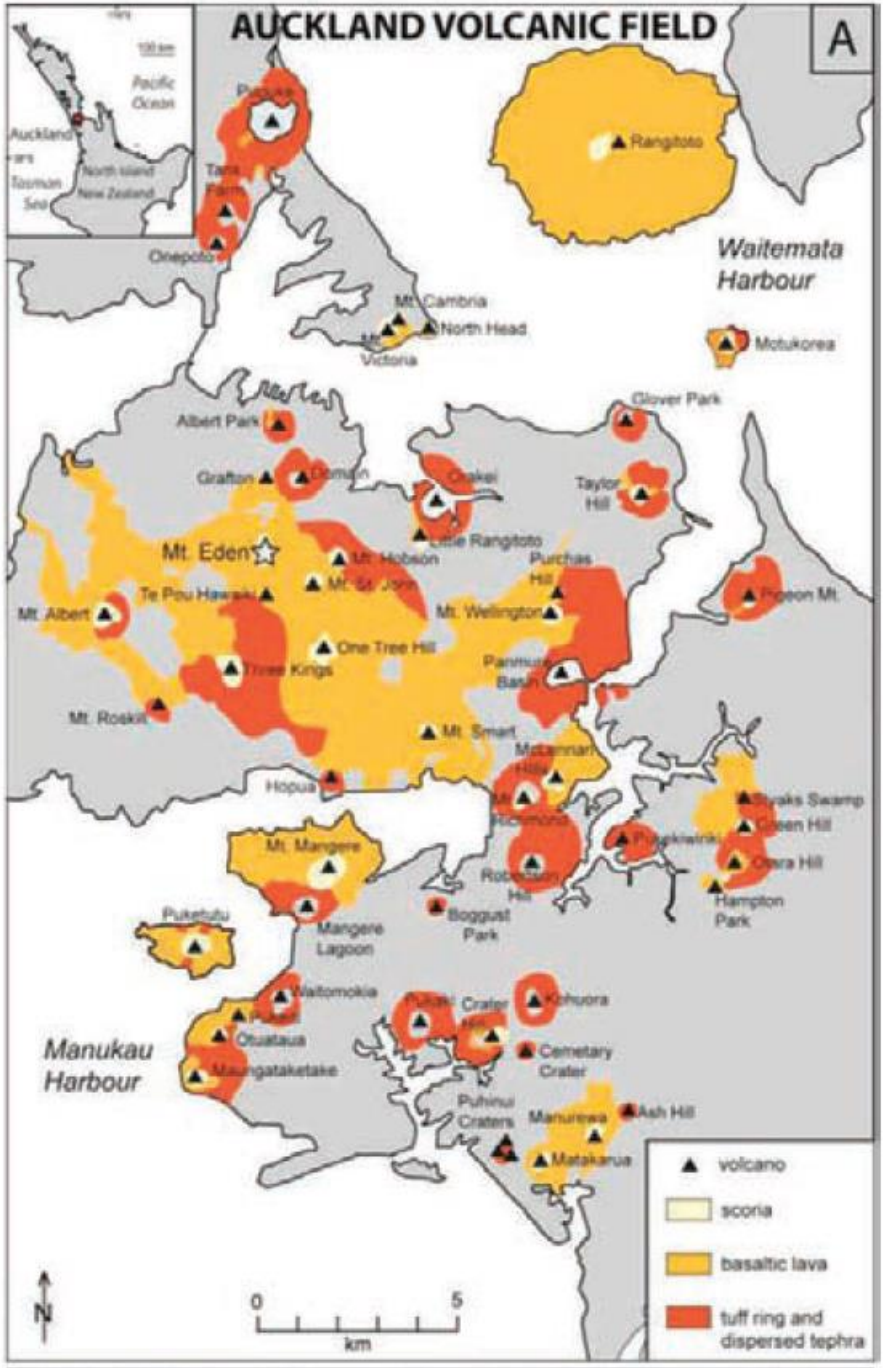
Background

- “800 million people live within 100 km of an active volcano in 86 countries and additional overseas territories worldwide”.
- The Auckland City is built on top of the Auckland Volcanic Field (AVF),
- The field is likely to erupt again: the most recent eruption, Rangitoto, was only 550 years ago .

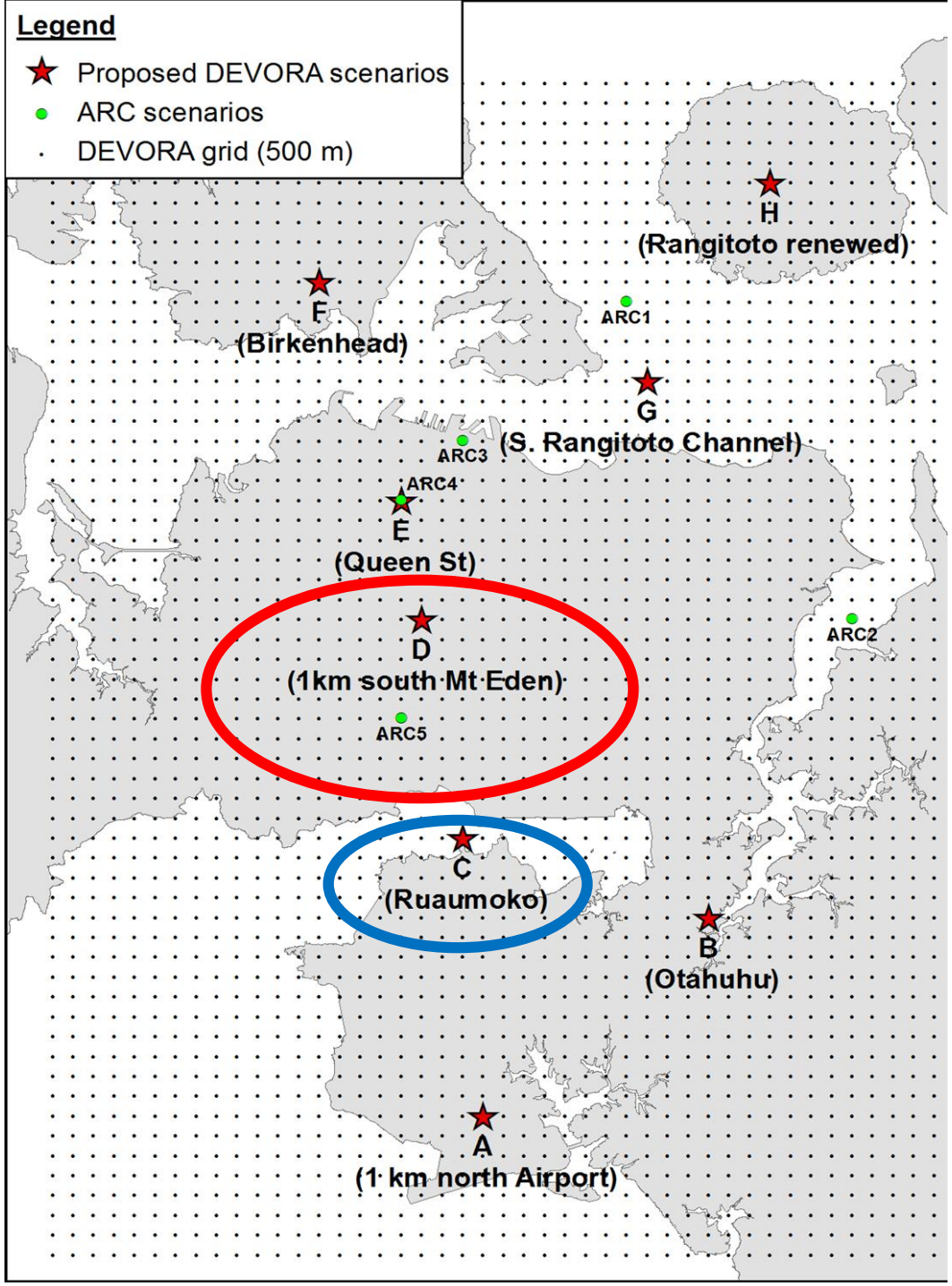
(Global Volcanic Hazards and Risk)





Characteristic of Study Area

- Auckland has a unique geographical location.
- Natural bottle neck
- Congested transportation network
- Unique topography
- Situated on active volcanic field
- 8 proposed eruption Scenario by Determining Volcanic Risk in Auckland (DEVORA)
- Total 411 zones in Auckland (Auckland City Council)



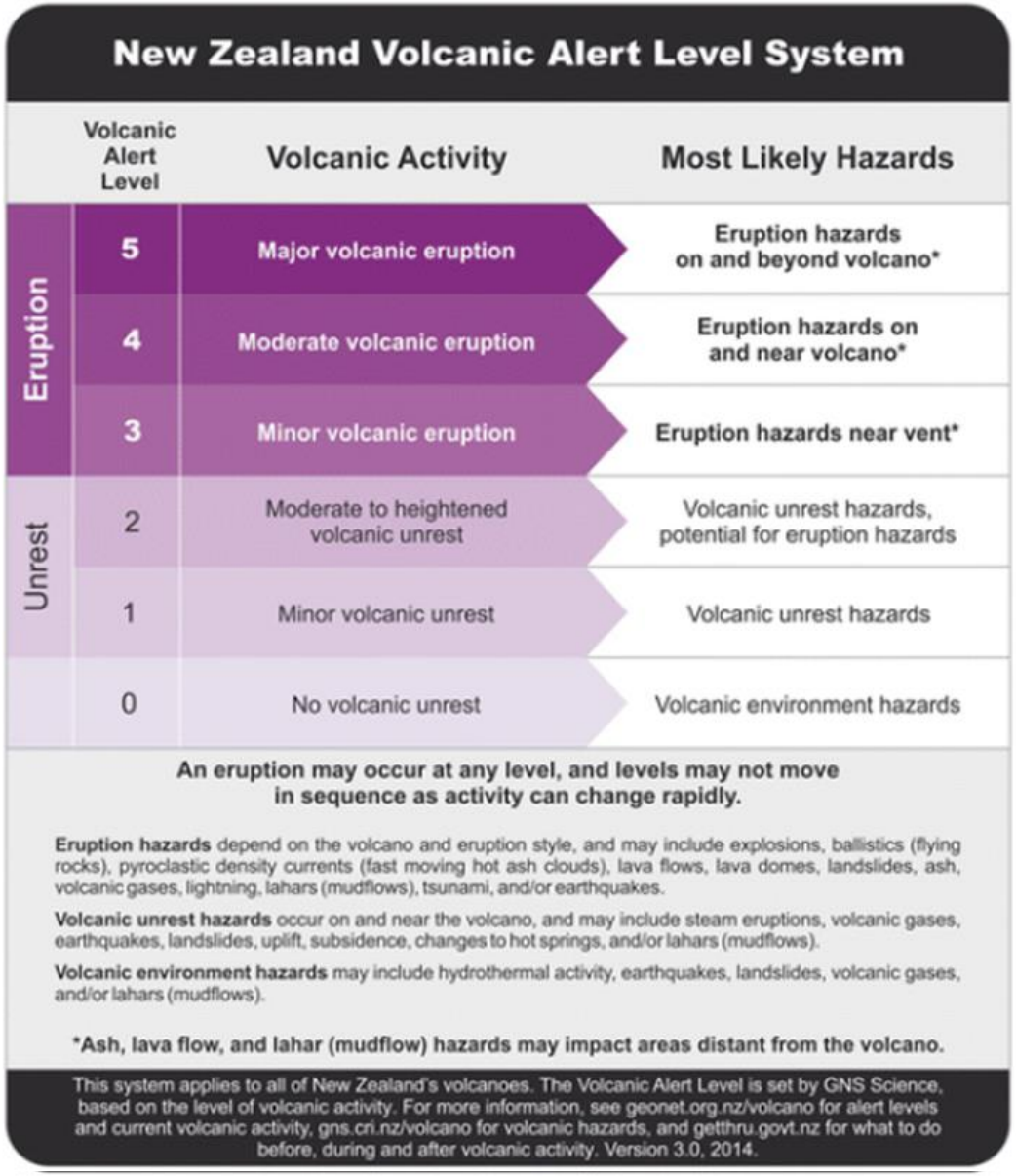
Ruaumoko Scenario Exercise (Staged Evacuation)

UC developed Mt Ruaumoko Scenario in AVF for an educational simulation exercise. The scenario spans 10 week (6 feb – 14 April)
(ERI Research Report, 2015)

- On 22 feb VAL increase from 0 to 1, there will be self-evacuation by some concerned residence.

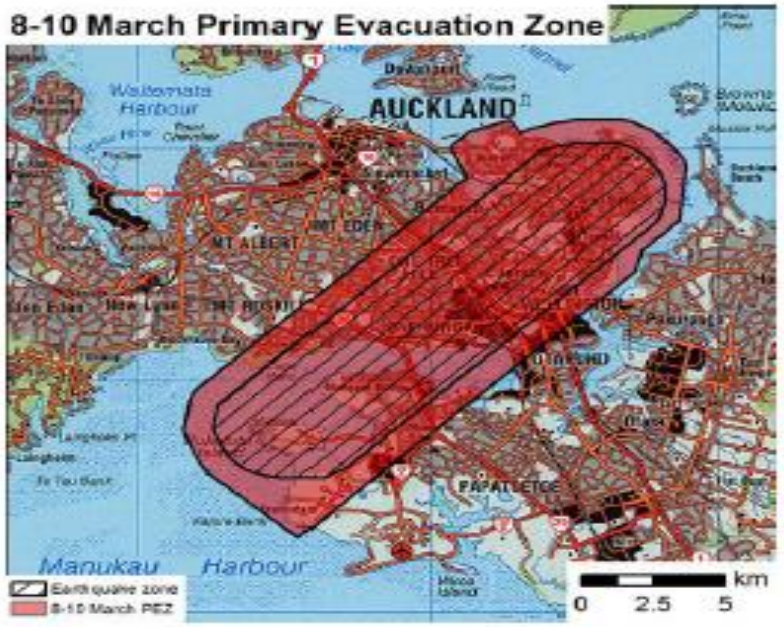
- During Exercise, the evacuation continued to 15 march (MCDEM, 2008).

Limitations: They considered only night time scenario for the calculation of population.
No Traffic Simulation used to calculate clearance time of evacuation.

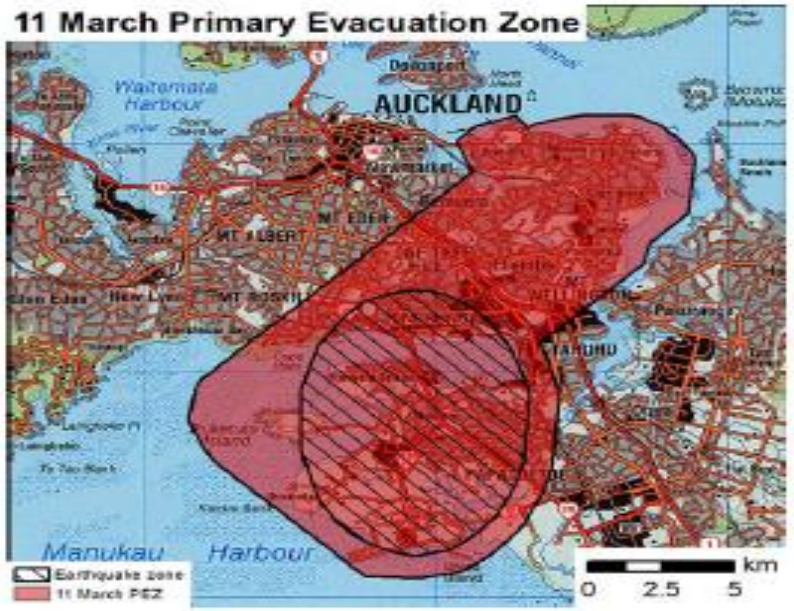


New Zealand Volcanic Alert Level (VAL) version 3.0 (Potter et al.,2014)

Ruaumoko Exercise



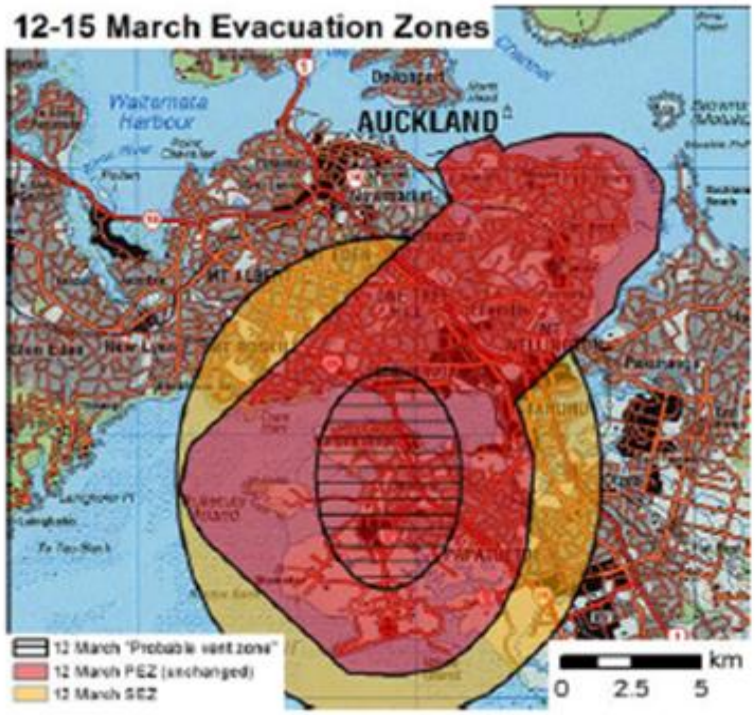
Initial evacuation was called on **8 march** when VAL goes from 1 to 2. 199,200 people will be affected.

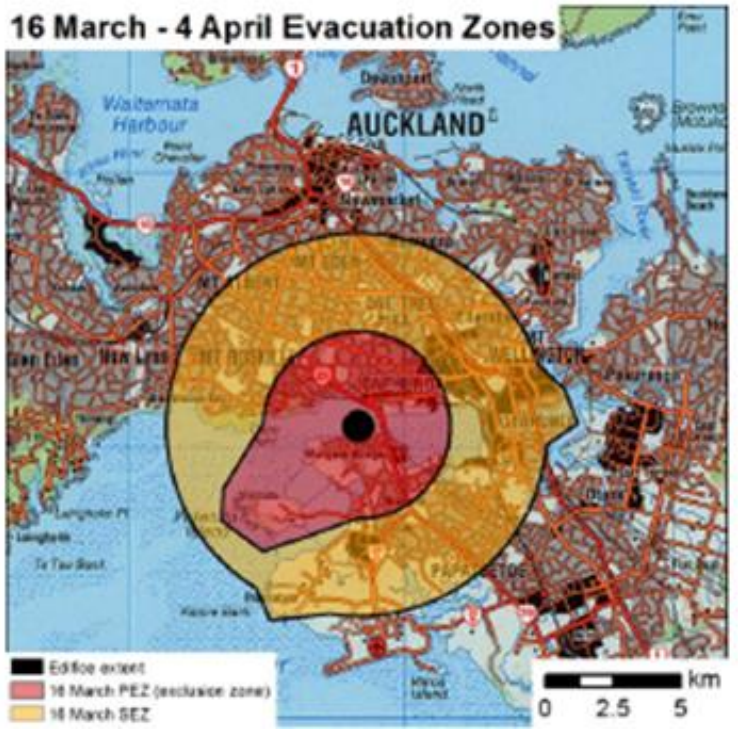


By **11 march additional** 54,400 are effected by the extended evacuation zone. Up to this point total evacuees 253700.

(MCDEM, 2008).

Ruaumoko Exercise





On **12 March volcanic** gas is detected. evacuation announced at 10:00 AM and effective from **12 noon on 13 March** and continued into 14 march. At this stage PEZ(3km) and SEZ (5km) will be evacuated (362,100 people). Total 434,400 including 72,300 shadow people of 1 km buffer zone.

(MCDEM, 2008).

Evacuation Studies using Simulation (Response / Pre Disaster Resilience / Increased Demand Scenario)

Authors	MOEs	Methodology	Case Study	Gaps
Zhang et al.(2013)	Total no. of Trips, Total Veh. Hours, Avg. Travel Time, Avg. Travel Speed, **Clearance Time**	TRANSIMS	Hurricane Evacuation for Gulf Coast Region, (Houstan Galveston)	Vehicle removed with travel time 3 hr longer than normal conditions. Computer Processing Limitation, Could not cover full travel condition.
Naghawi & Wolshon (2010)	Average Travel Time and Total Evacuation Time	TRANSIMS, ANOVA	Hurricane Evacuation for New Orleans	Only checked the improvement in evacuation time using transit
Chen (2008)	Evacuation Time	Vissim V4	Hurricane Evacuation, Galveston Island, USA	35,219 vehicles, 58,000 people, Small Island (only 1 exit used), calibration not even discussed.
Chen et al. (2006)	Evacuation Time	VISSIM V3.70	Hurricane Evacuation for Florida Keys, USA	Peninsula, calibration not even discussed.

Gap 01: Few mass evacuation studies available for coastal areas using micro simulation in case of Hurricane. In these studies all Traffic goes in one direction.

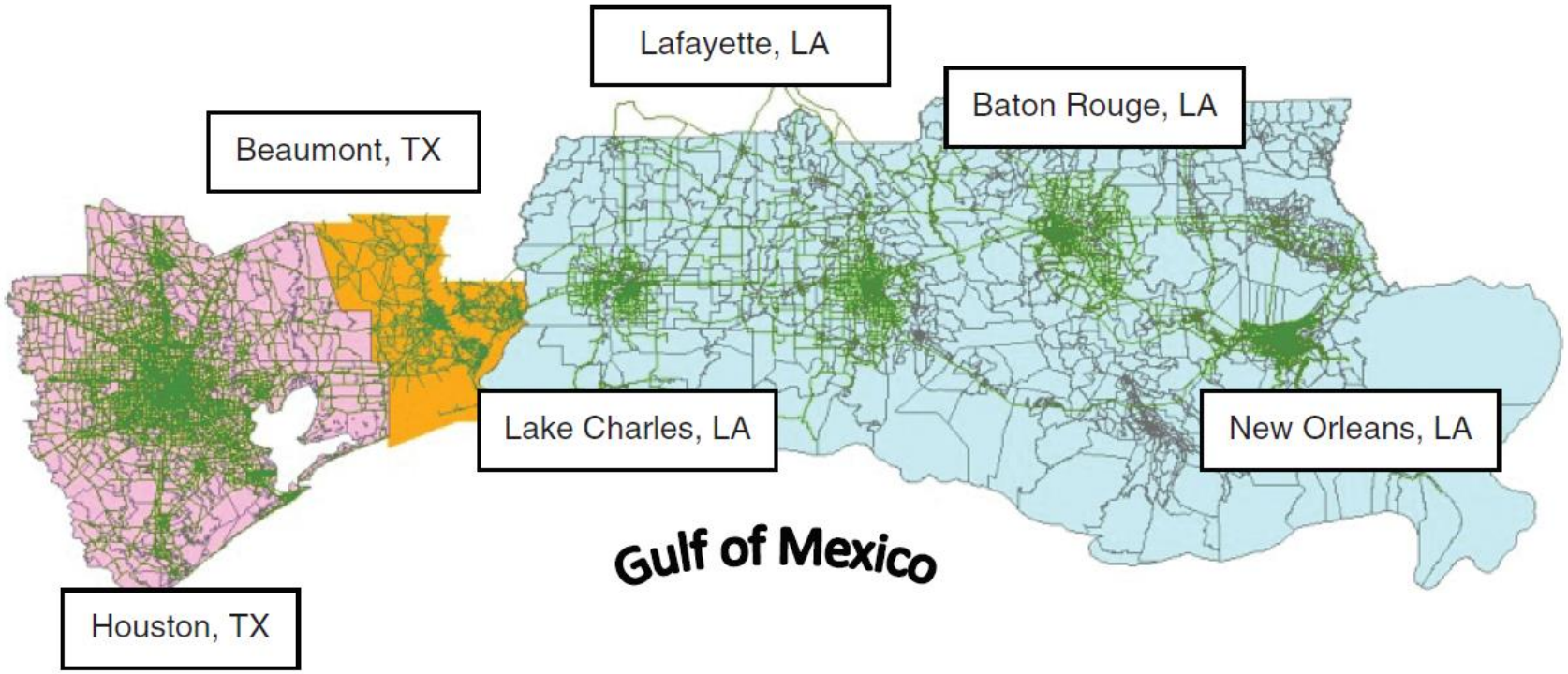
Evacuation Studies using Simulation (Response / Pre Disaster Resilience / Increased Demand Scenario)

Authors	MOEs	Methodology	Case Study	Gaps
Thomson et al. (2014)	Total Network Clearance Time	TransCAD	Auckland	Software Limitations. Model was not calibrated.
Jayananthan & Jayasinghe (2016)	Total Clearance Time	AIMSUN	Auckland	Model was not Calibrated due to limited time

Gap 01: Two mass evacuation studies available for Auckland City, only one use micro simulation. Model was not calibrated

Objective 01: Evaluate total clearance time for “mass evacuation of Auckland city” before eruption occurs using Calibrated model.

Gulf Coast Megaregion (Zhang et al. 2013)

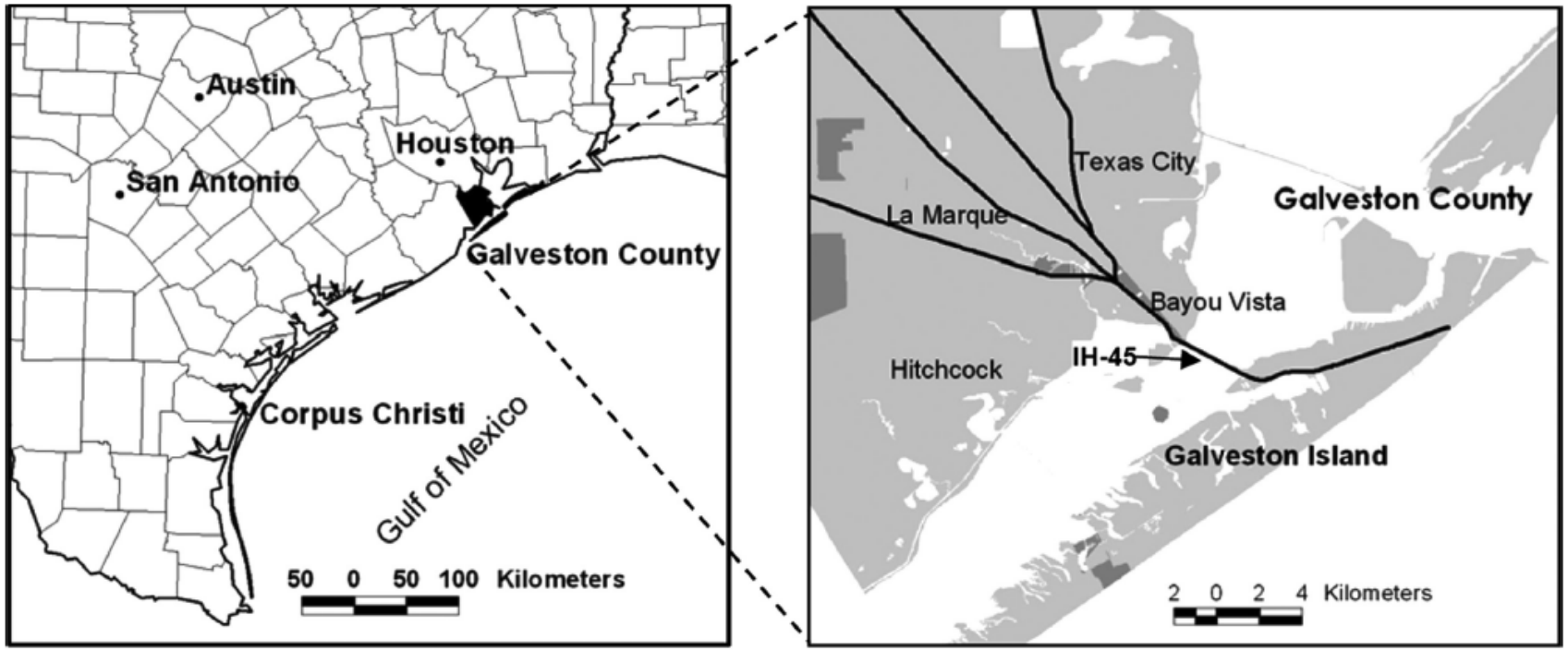


Simulation Results (Zhang et al. 2013)

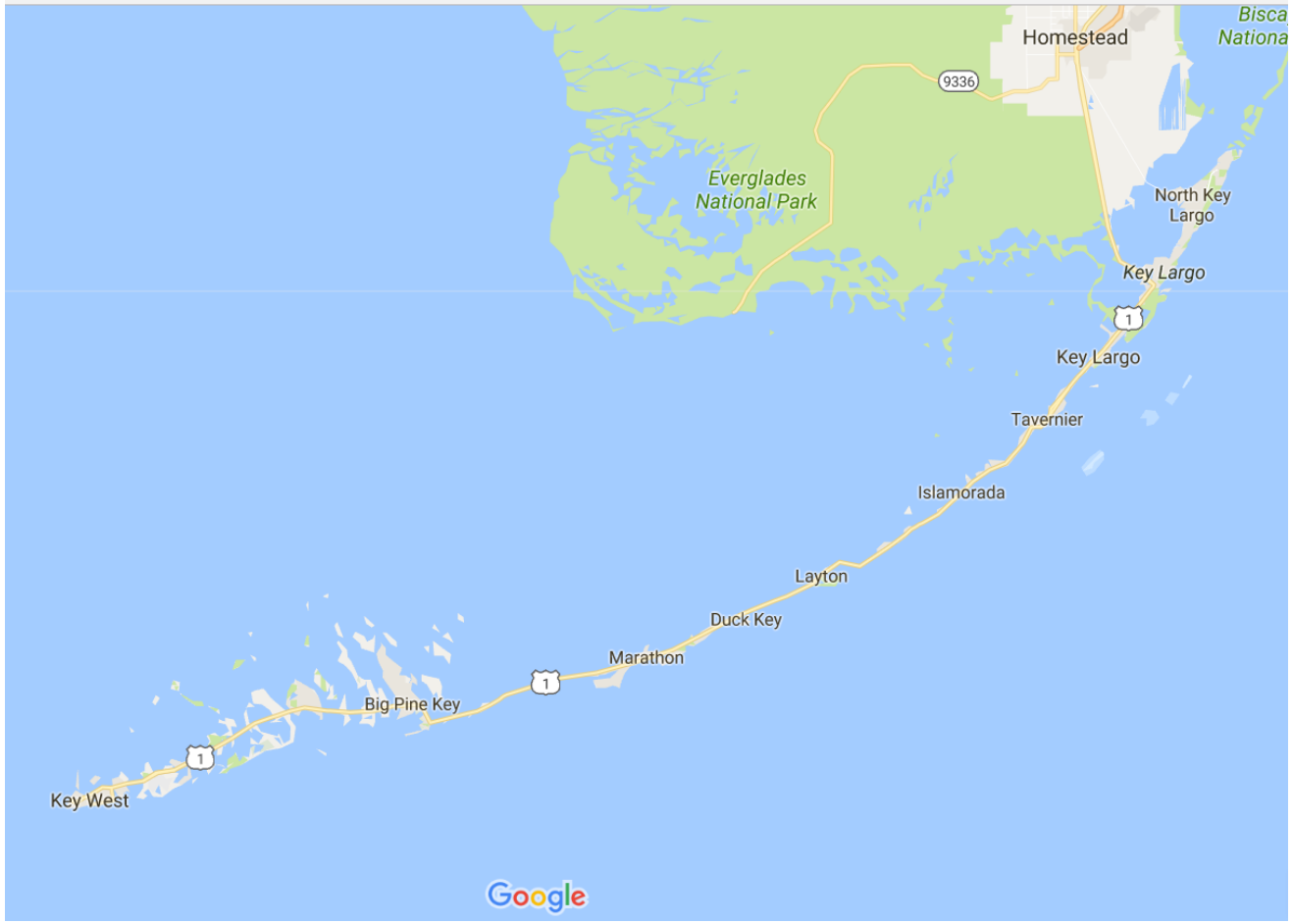
Scenario	Time	Total Trips	Total Vehicle Hours	Total Vehicle Miles	Avg. Travel Time (h:min)	Avg. Travel Speed (mph)	Avg. Trip Length (mi)	Vehicles Removed	Contraflow Plan
1	Day 1	417,808	1,287,164	52,916,443	3:04	51.6	126.7	13,765	Plan 1
	Day 2	548,878	1,714,707	61,970,935	3:07	48.1	112.8	9,193	
	Total	966,686	3,001,871	114,887,378	3:06	49.9	119.7	22,958	
2a	Day 1	580,370	2,385,837	74,755,968	4:06	43.1	128.8	103,673	Plan 1
	Day 2	549,154	1,261,835	56,460,951	2:19	49.0	104.0	10,672	
	Total	1,129,524	3,647,672	131,216,919	3:13	46.1	116.4	114,345	
2b	Day 1	580,370	2,176,945	74,540,040	3:45	44.7	128.4	77,841	Plan 2
	Day 2	549,154	1,093,388	57,285,191	2:00	53.7	105.6	21,735	
	Total	1,129,524	3,270,332	131,825,230	2:52	49.2	117.0	99,576	
2c	Day 1	580,370	2,155,501	75,136,114	3:42	45.7	129.5	60,526	Plan 3
	Day 2	542,714	1,093,388	57,285,191	2:00	53.7	105.6	21,735	
	Total	1,123,084	3,248,888	132,421,305	2:51	49.7	117.5	82,261	
3a	Day 1	715,991	2,819,686	87,345,490	4:03	40.6	125.7	97,377	Plan 2
	Day 2	499,919	945,549	50,033,944	1:54	54.8	100.9	14,289	
	Total	1,215,910	3,765,235	137,379,434	2:58	47.7	113.3	111,666	
3b	Day 1	715,991	2,853,408	88,190,921	4:06	39.0	126.9	84,895	Plan 3
	Day 2	499,919	945,549	50,033,944	1:54	54.8	100.9	14,289	
	Total	1,215,910	3,798,957	138,224,865	3:00	46.9	113.9	99,184	
4[a]	Day 1	3,178,238	—	0	0:00	0.0	0.0	—	Plan 3
	Day 2	1,009,552	2,102,544	75,831,492	2:04	48.0	75.1	211,754	
	Total	1,009,552	2,102,544	75,831,492	1:02	48.0	75.1	211,754	
5	Day 1	344,280	999,179	48,919,898	2:54	53.2	142.1	22,306	Plan 3
	Day 2	559,037	1,753,492	77,686,720	3:08	50.7	139.0	125,558	
	Total	903,317	2,752,672	126,606,618	3:01	52.0	140.5	147,864	
6	Day 1	551,807	1,696,479	75,854,501	3:04	51.6	137.5	113,855	Plan 3
	Day 2	660,000	2,174,490	89,863,937	3:19	50	137	237,304	
	Total	1,211,807	3,870,968	165,718,438	3:11	50.7	137.4	351,159	

NOTE: Avg. = average; — = missing data.
[a]Scenario 4 would never fully execute the full simulation prior to failure.

Galveston County and Island (Chen, 2008)



Florida Keys (Chen et al., 2006)



Transport Network Resilience (Recovery / Post Disaster Resilience / Decreased Capacity Scenario)

Authors	MOEs	Network Approach	Case Study	Gap
Bhavathrathan (2015)	"capacity & operation cost".	Two-space genetic algorithm	Hypothetical Test Networks	Didn't use the simulation
Taylor & Susil-awati (2012)	Change to accessibility level	Accessibility model	Green Triangle road network	Didn't use the auctual case study
Ip and Wang (2011)	Avg. no. of links b/w nodes	Optimization Model	Chines railway Network	It was for , not for roadways
Ash and Newth (2007)	Load Capacity	Evolutionary Algorithm	Hypothetical Test Network	Didn't use simulation
Matisziw and Murray (2007)	Vital Links	Optimization Model	Ohio Interstate System	No simulation
Rosenkrantz et al.	Max no. of node failure	Algorithms	No case study	

Vulnerability Analysis (Recovery / Post Disaster Resilience / Decreased Capacity Scenario)

Authors	MOEs	Methodology	Case Study	Gaps
Miramontes, (2016)	Network delay, frontage road delay, queue length	Mesoscopic (DynusT,2015)	El Paso Network	Micro simulation
Kim and yeo (2016)	Density, Overflow	MFD based Vulnerability index. AIMSUN 7	Gangnum city	Don't have enough data to model MFD
Jenelius and Mattsson (2015)	Travel pattern and network density	GIS and Algorithms	Sweden road network	No Traffic Simulation
Jenelius and Mattsson (2012)	Level of Internal, outbound, and in bound travel demand of the effective area	Grid-based vulnerability analysis	Sweden road network	No Traffic Simulation

Gap 02: Most of the road network vulnerability and Resilience studies are Conceptual or analytical or GIS based. Very Few road network resilience and vulnerability studies use macroscopic or mesoscopic traffic simulation software for densely populated urban area.

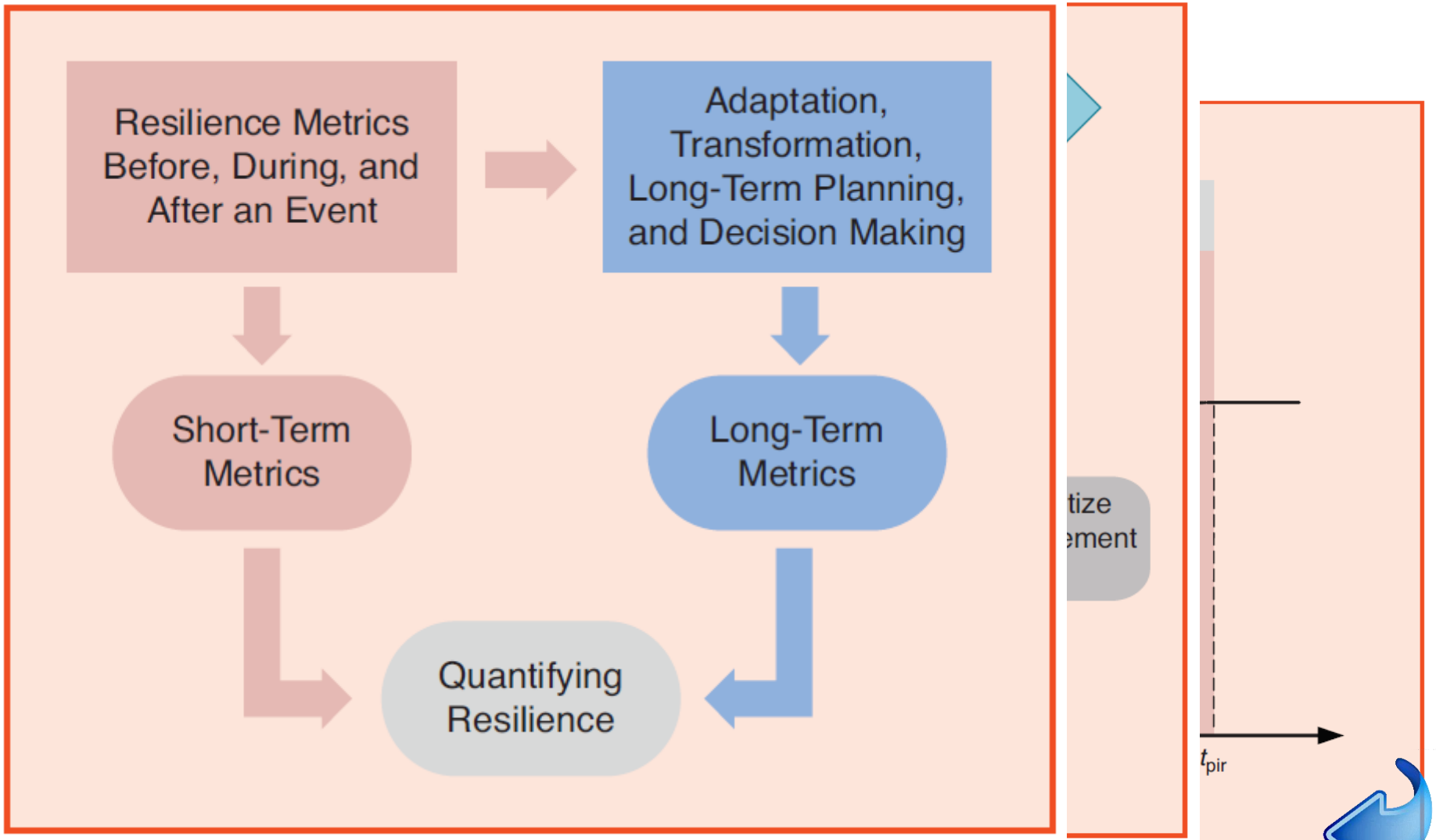
No Technical Transportation vulnerability Analysis has bee done for Auckland using traffic simulation for any natural or manmade hazard (Volcanic Hazard).

Objective 02: Evaluate performance of network after volcanic eruption (Post Disaster Scenario).

Vulnerability analyse of Urban Transportation Network for Auckland using traffic simulation software.

Asses the resilience of transportation network for post disaster scenario.

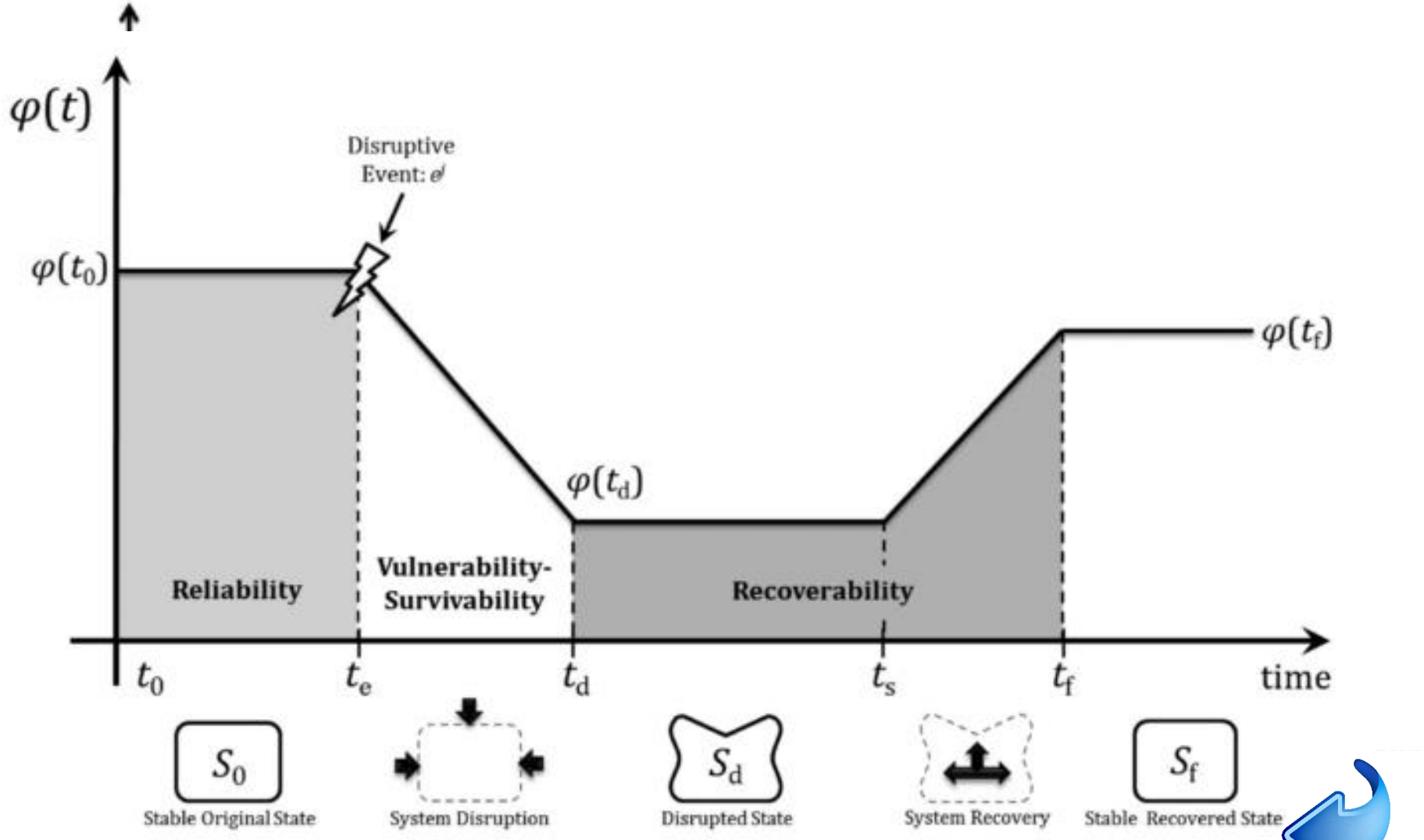
Conceptual Resilience Framework



Conceptual long-term resilience framework

Panteli and Mancarella, 2015

Conceptual Resilience Framework



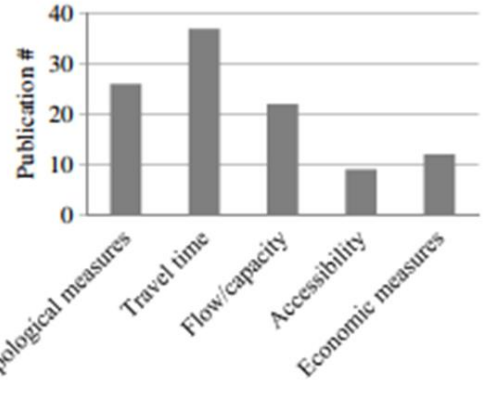
Graphical Depiction of State Transitions over Time (Baroud et al. 2014)

Conceptual Resilience Framework

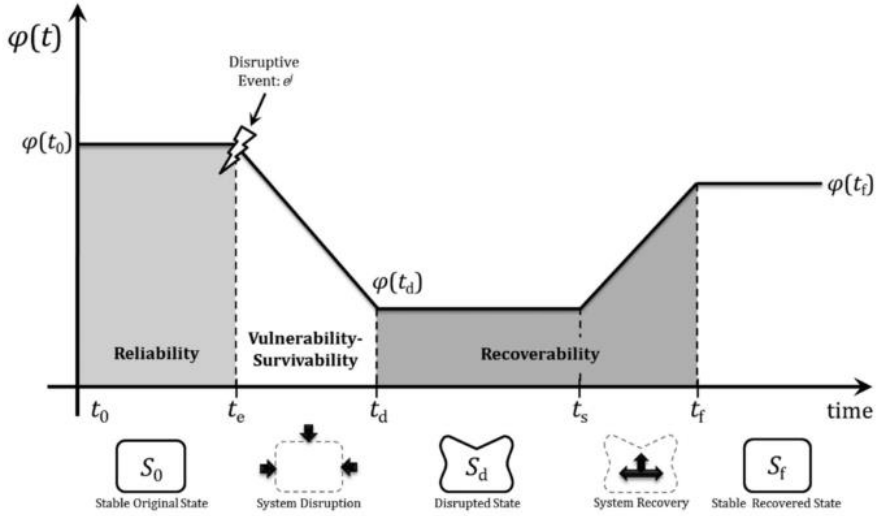
Gap 03: Resilience Frameworks do not explain Pre Disaster Situation (increased demand scenario)

Objective 03: Develop Framework for Urban Transportation Network Resilience (UTNR), which encompass both pre disaster and post disaster scenarios.

Develop a single measure of resilience for Urban Transportation Network.



Number of disaster assessment publications on each MOE
(Faturechi R. and Miller-Hooks E. , 2014)



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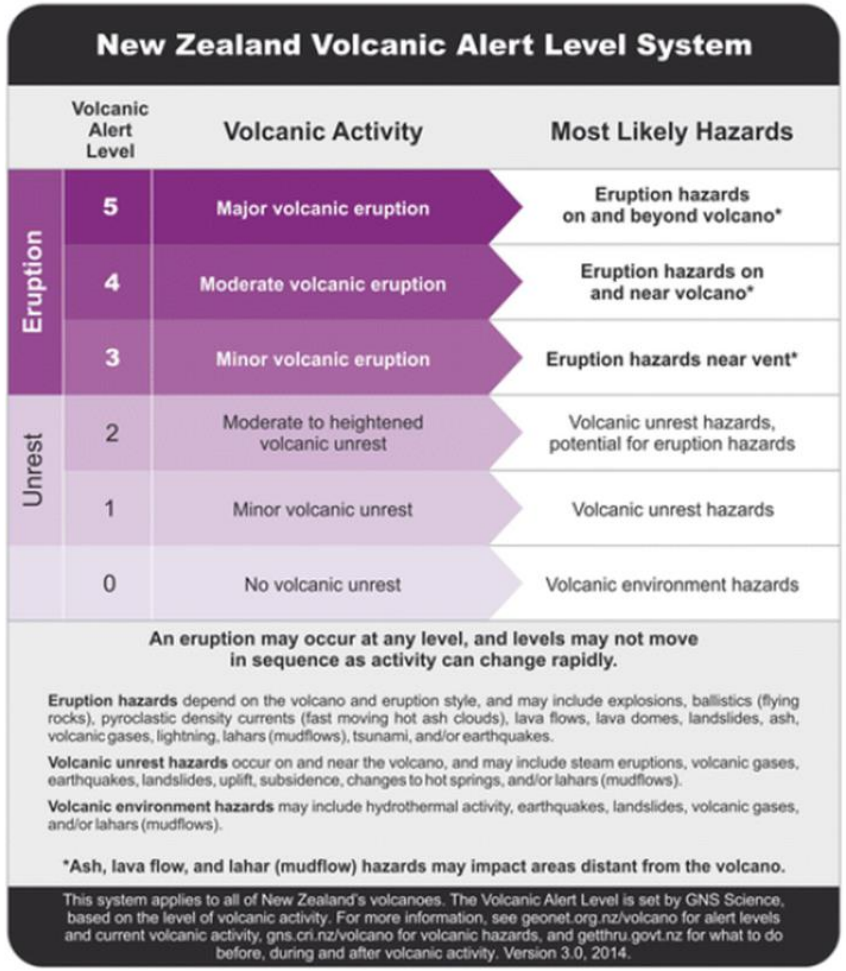


New Zealand Volcanic Alert Level (VAL) version 3.0 (Potter et al.,2014)

Aims & Objectives

The main aim of this research is to access the resilience of Urban Transportation Network using Traffic simulation software (AIMSUN).

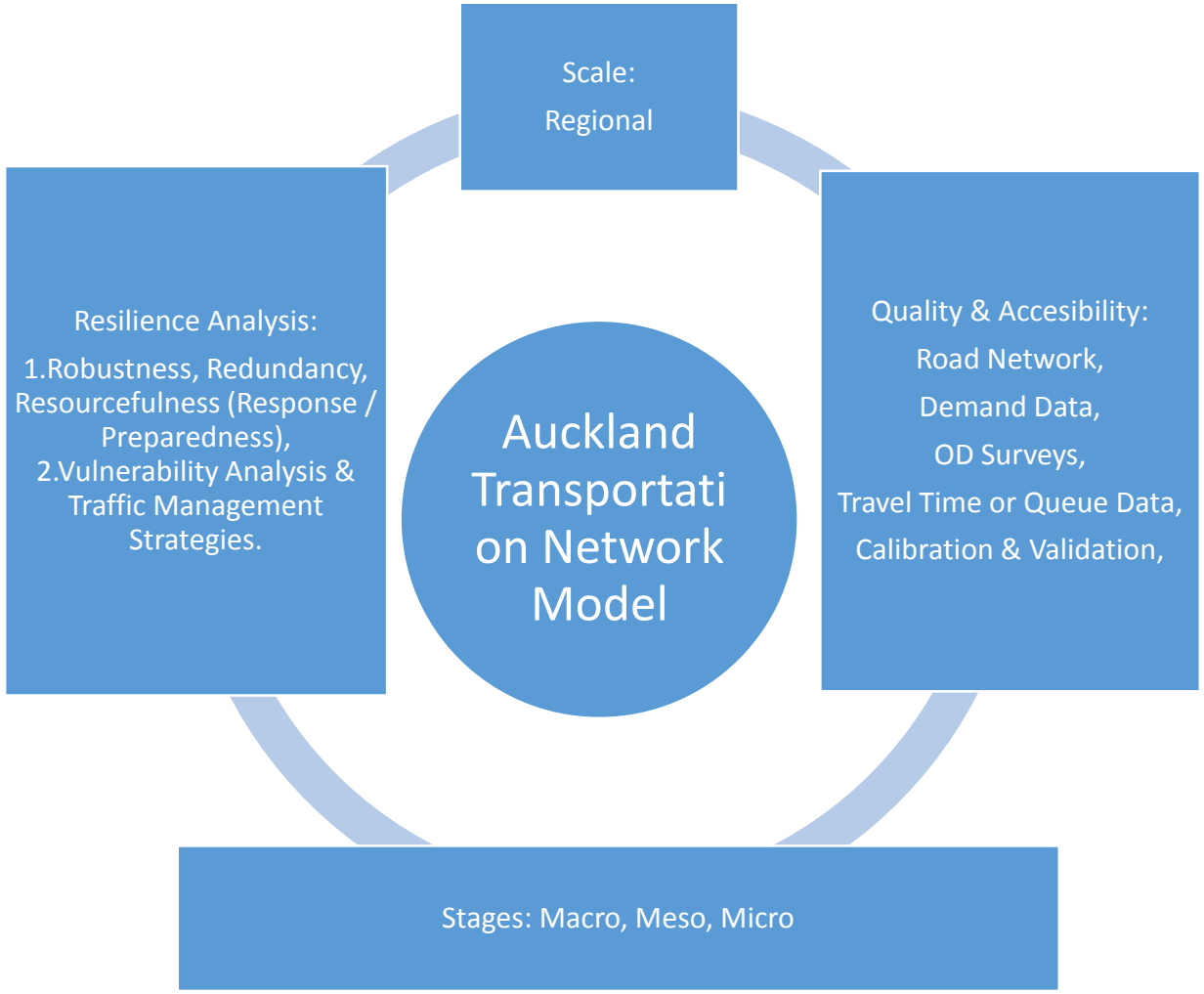
- **Objective 01:** Evaluate total clearance time for “mass evacuation of Auckland city” before eruption occurs using calibrated model.

- **Objective 02:** Evaluate performance of network after volcanic eruption (Post Disaster Scenario).

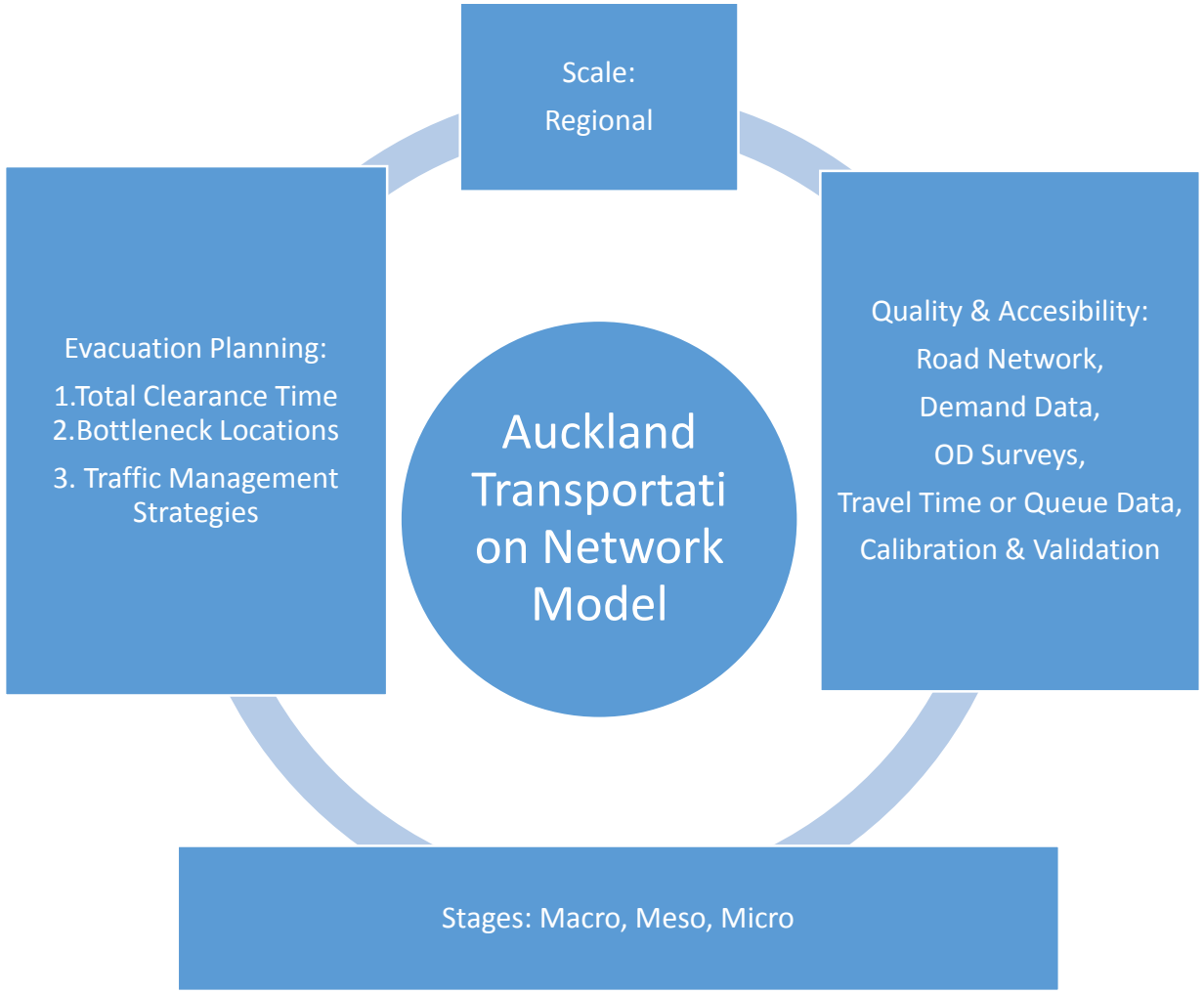
Vulnerability analyse of Urban Transportation Network for Auckland using Traffic simulation software.

- **Objective 03:** Develop Framework for Urban Transportation Network Resilience (UTNR), which encompass both pre disaster and post disaster scenarios.

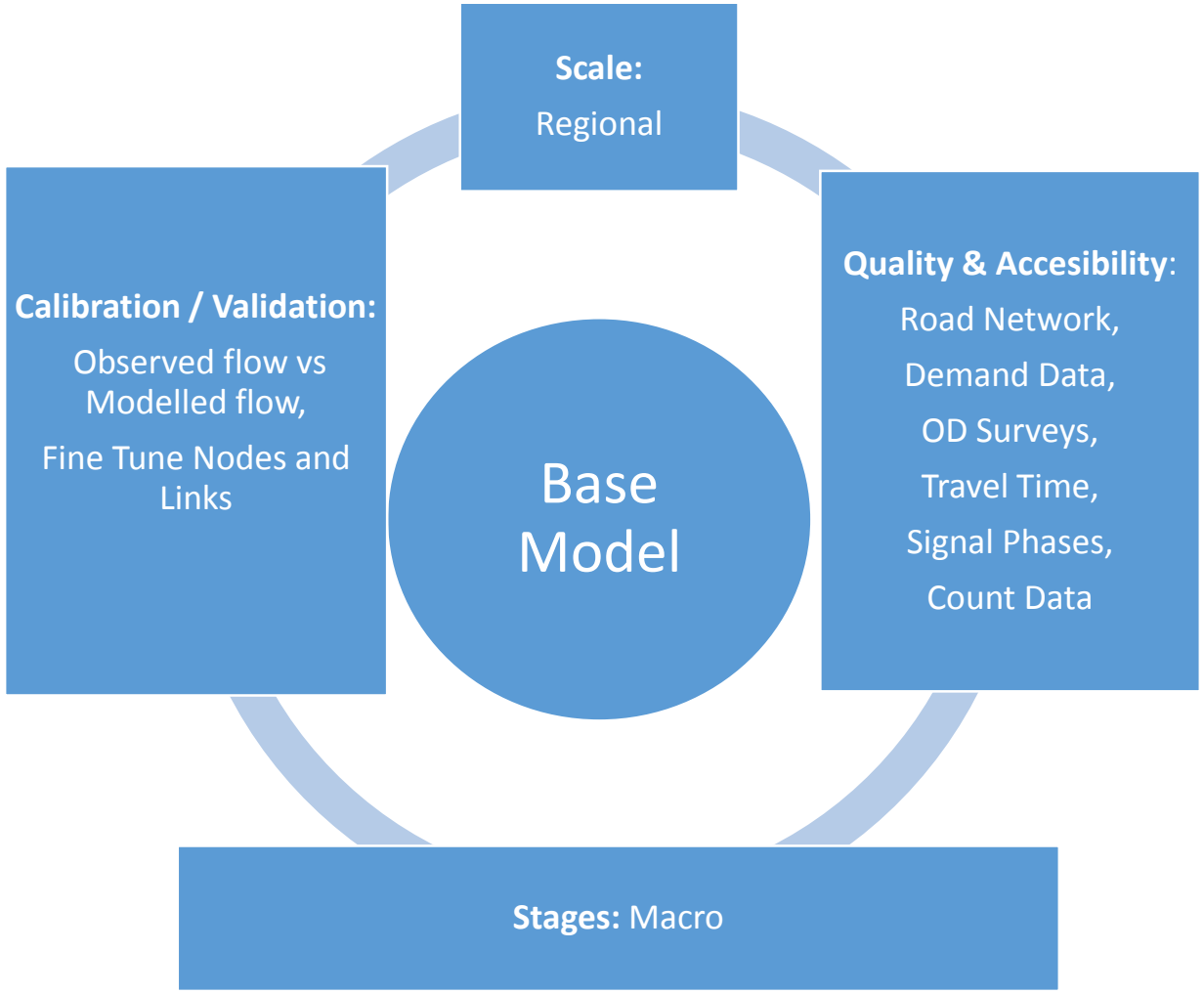
Heuristic Approach (General Methodology)



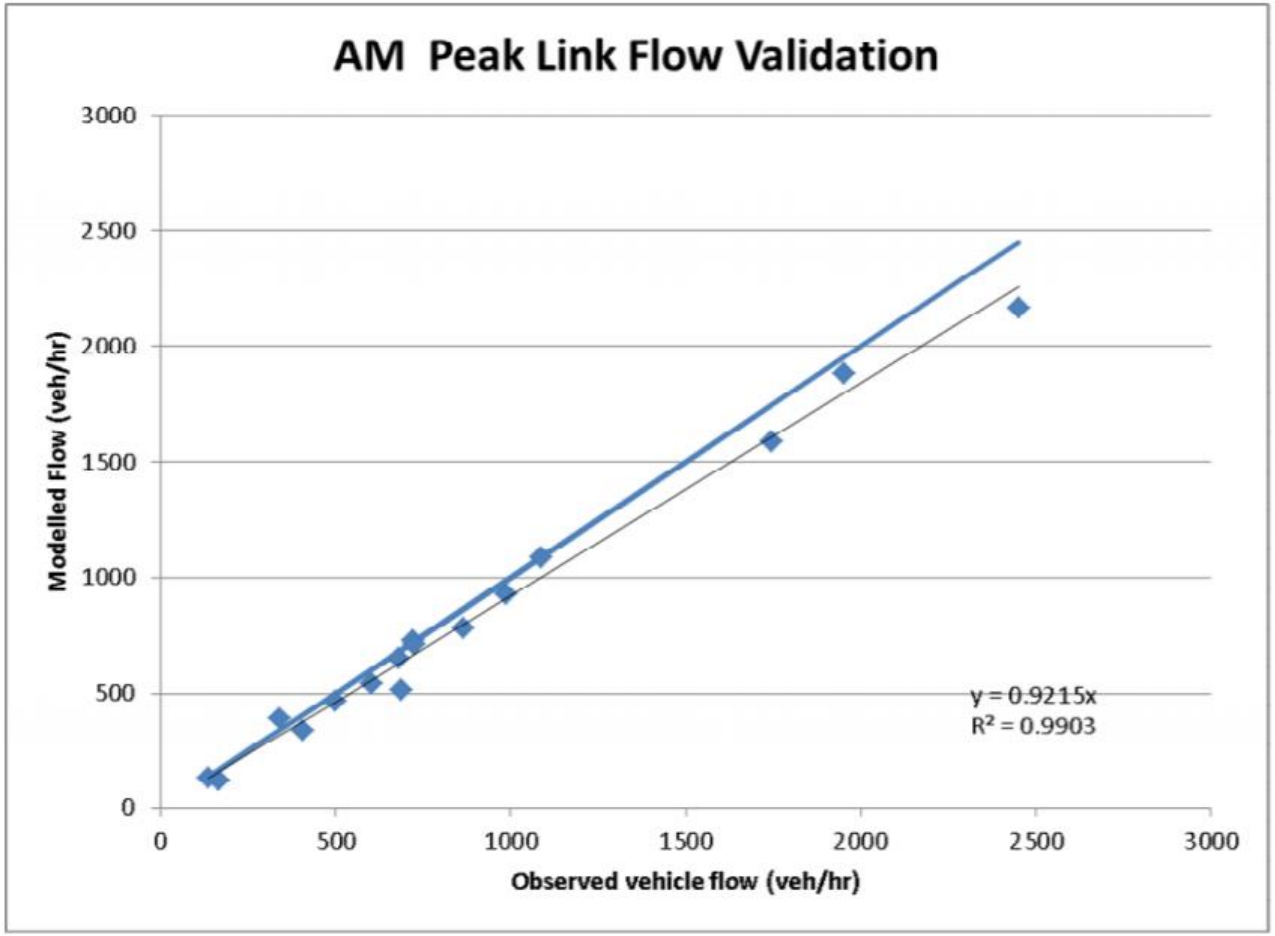
Heuristic Approach (General Methodology)



Stage 1 (Macro)



Count Comparison



(Penlink Traffic & Economic Analysis by BECA, June 2014)

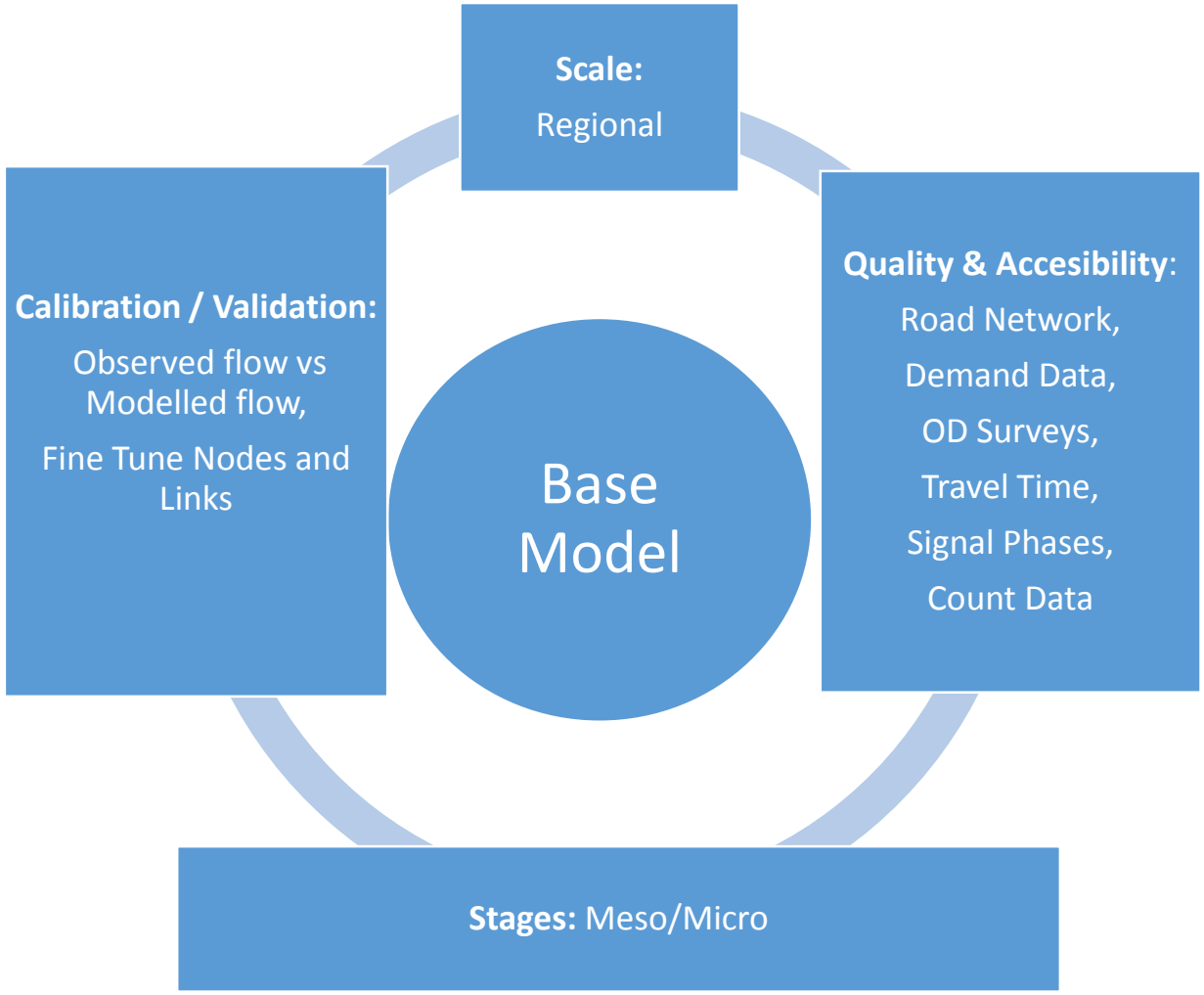
Validation Criteria used by BECA for Penlink

Measure	Target	AM	IP	PM
GEH Percentage (Individual Link)				
GEH <5	60%	88%	94%	88%
GEH <10	95%	100%	100%	100%
GEH <12	100%	100%	100%	100%
RMSE	<30%	12%	9%	12%

EEM suggested criteria

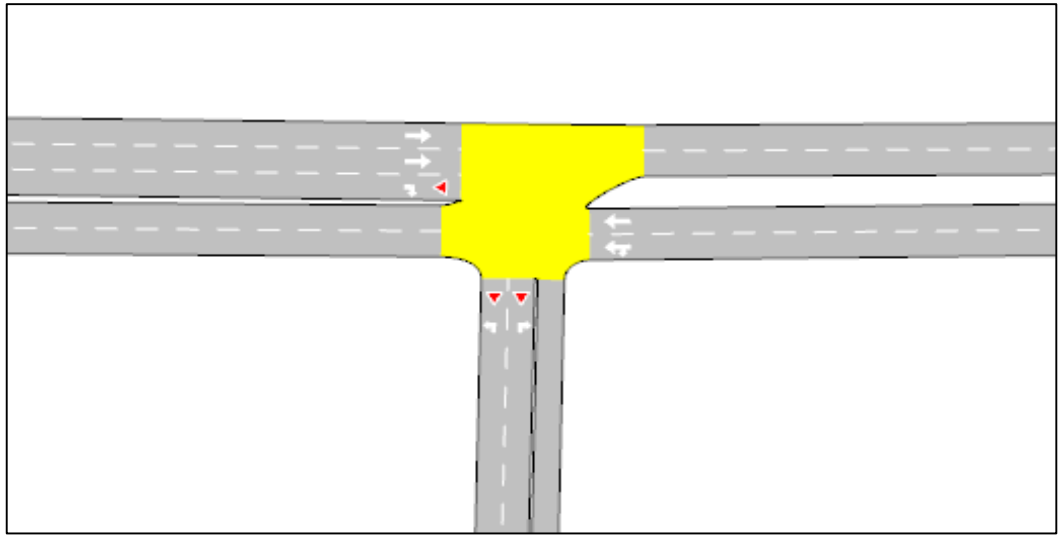
(Penlink Traffic & Economic Analysis by BECA, June 2014)

Stage 2 & 3 (Meso & Micro)

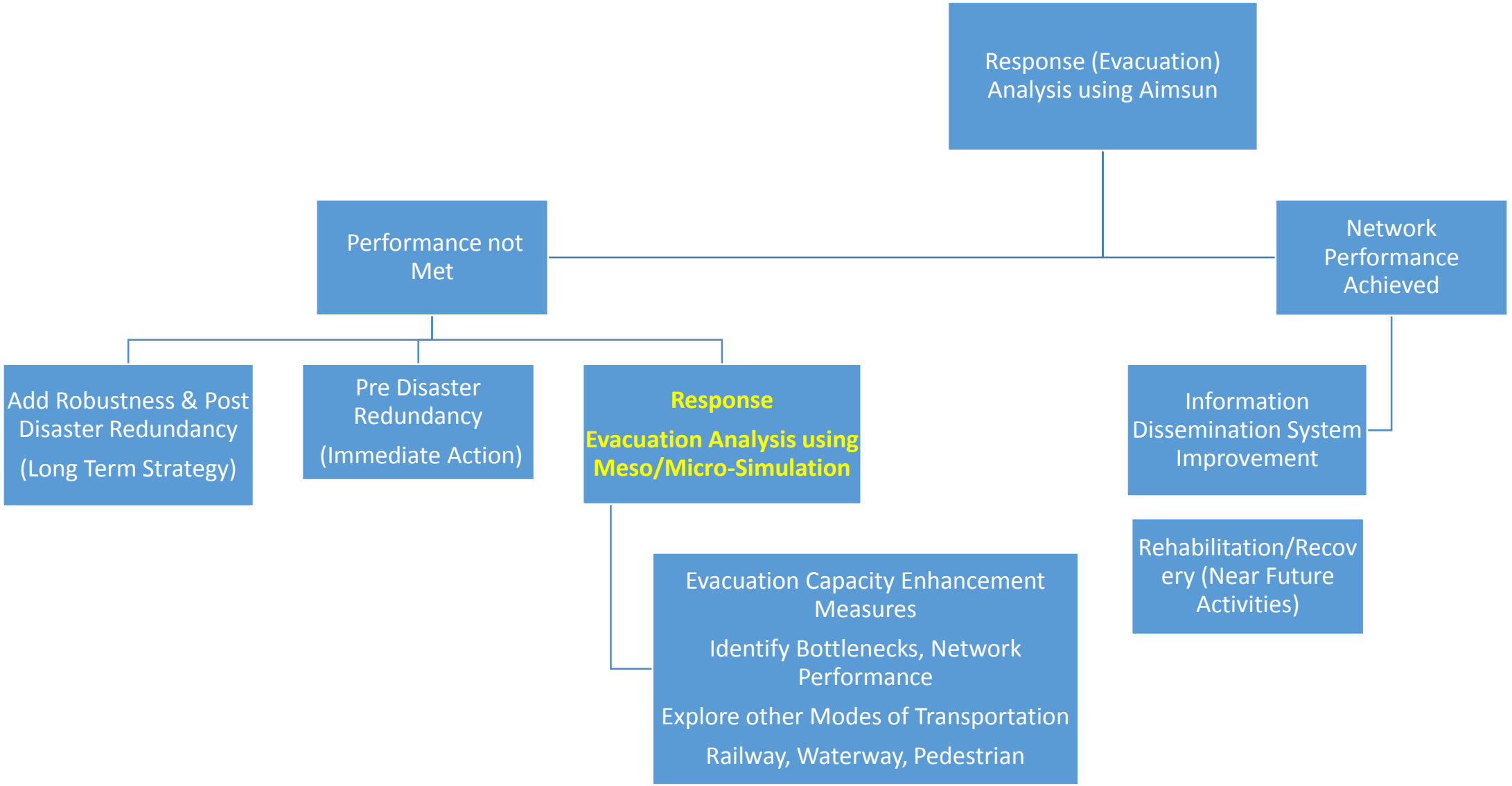


AIMSUN Micro Parameters						
		ISM	FSM	IGWTF	FGWTF	RT
Major	RT	1.7	1.0	1.0	1.5	
Minor	RT	3.3	2.0	1.5	2.0	1.2
	LT	0.8	0.5	0.5	1.0	

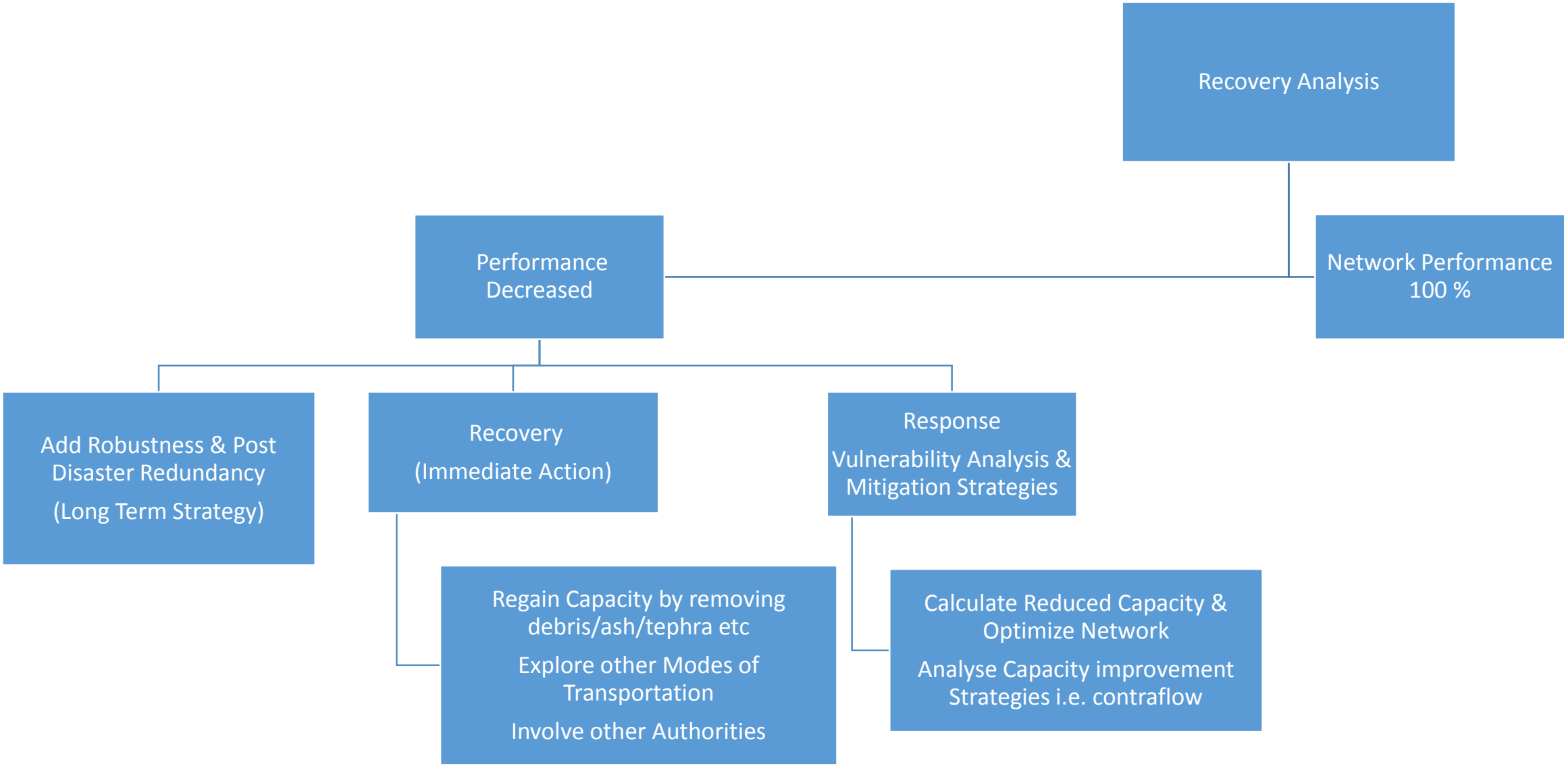
AIMSUN Meso Parameters					
		ISM	FSM	GWTF	RT
Major	RT	6.0	4.5	1.5	
Minor	RT	10.1	9.4	7.5	1.8
	LT	3.5	2.5	0.5	



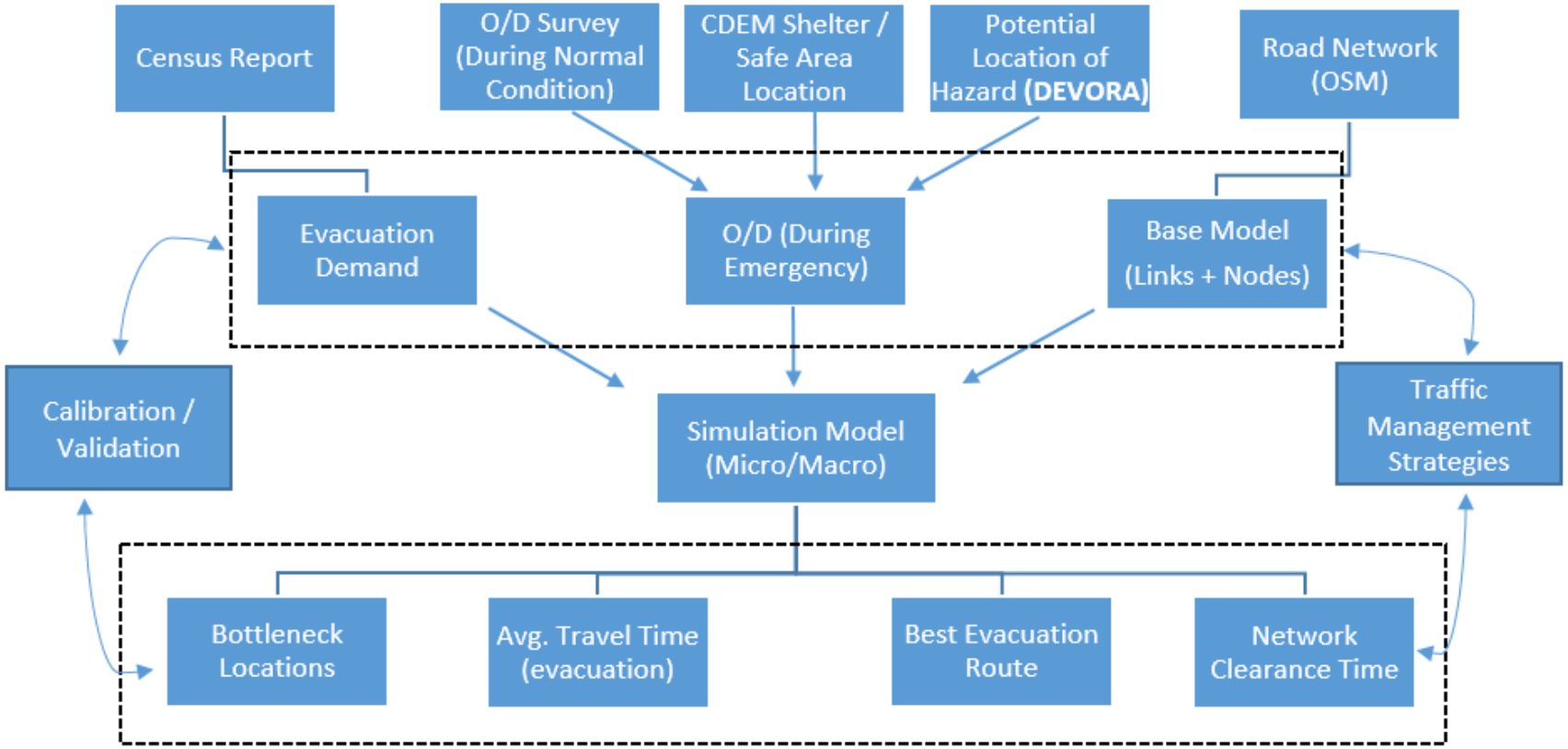
Methodology (Pre Disaster)



Methodology (Post Disaster)

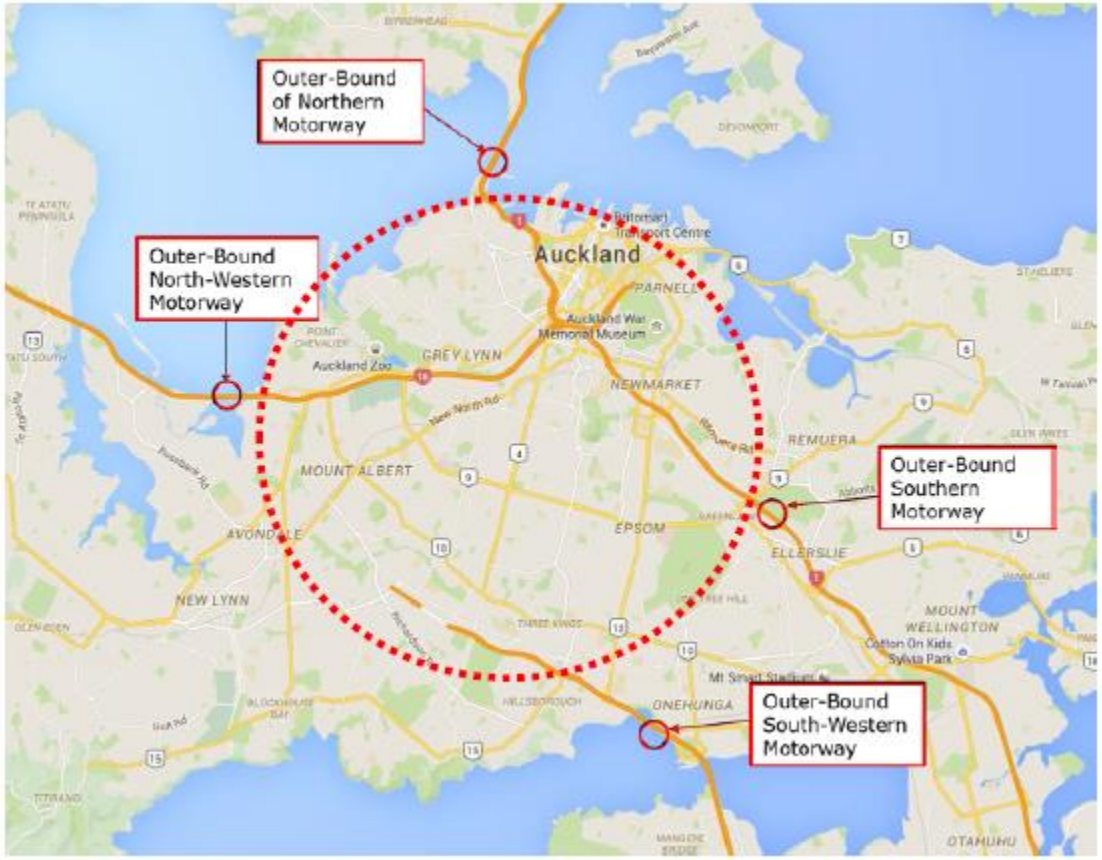


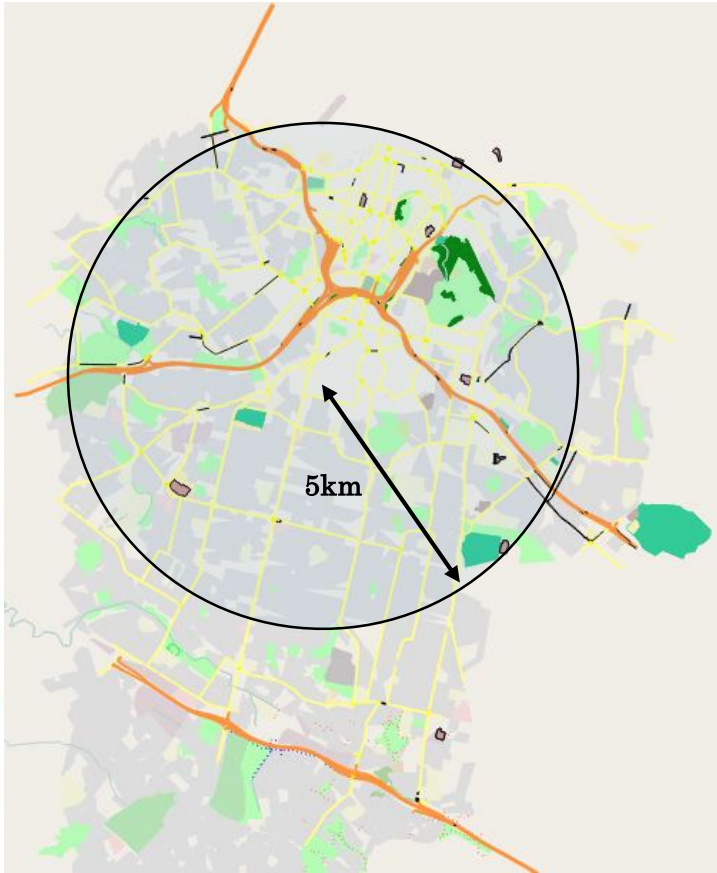
Methodology (Evacuation / Pre Disaster Model Preparation)

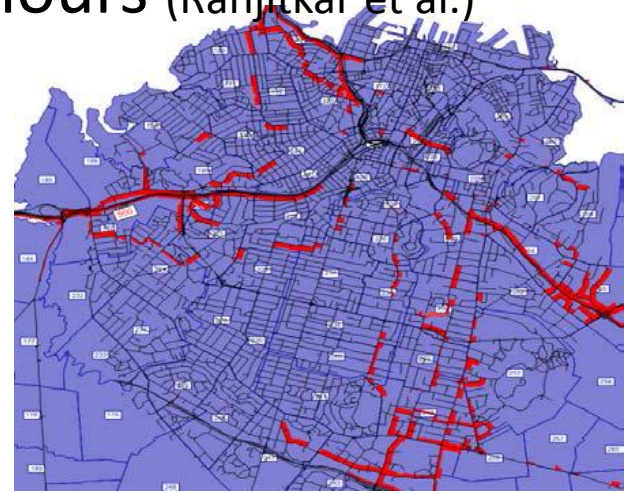


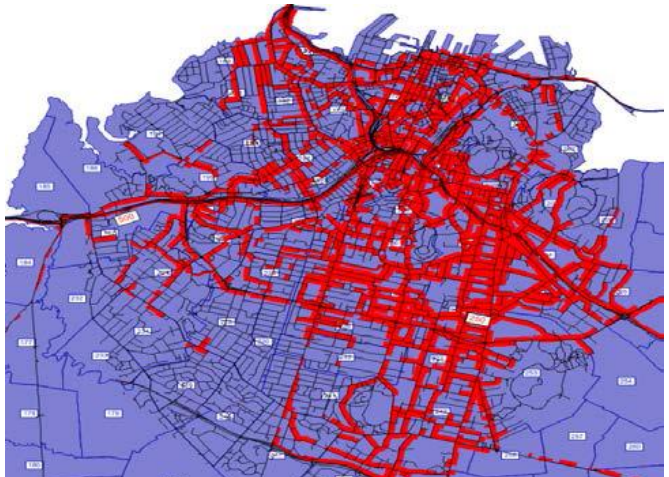
1 km South of Mt. Eden

Total 411 zones in Auckland (Auckland City Council) 66 (Origin),345 (Destination). Calculated total clearance time 10 to 14 hours (Ranjitkar et al.)









Thanks

To be continued……..