Performance Based Economic Loss Assessment Due to a Hypothetical Large Southern California Earthquake Based on the Disruption and Recovery of Port of Los Angeles Freight Traffic

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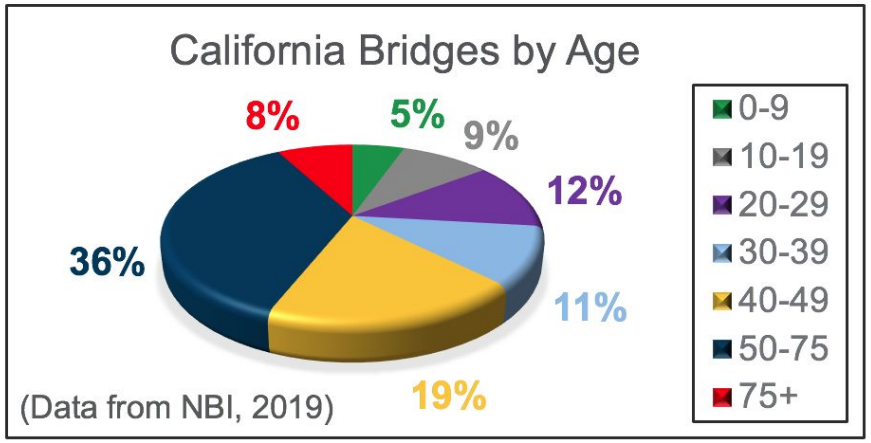
Disaster Resilience

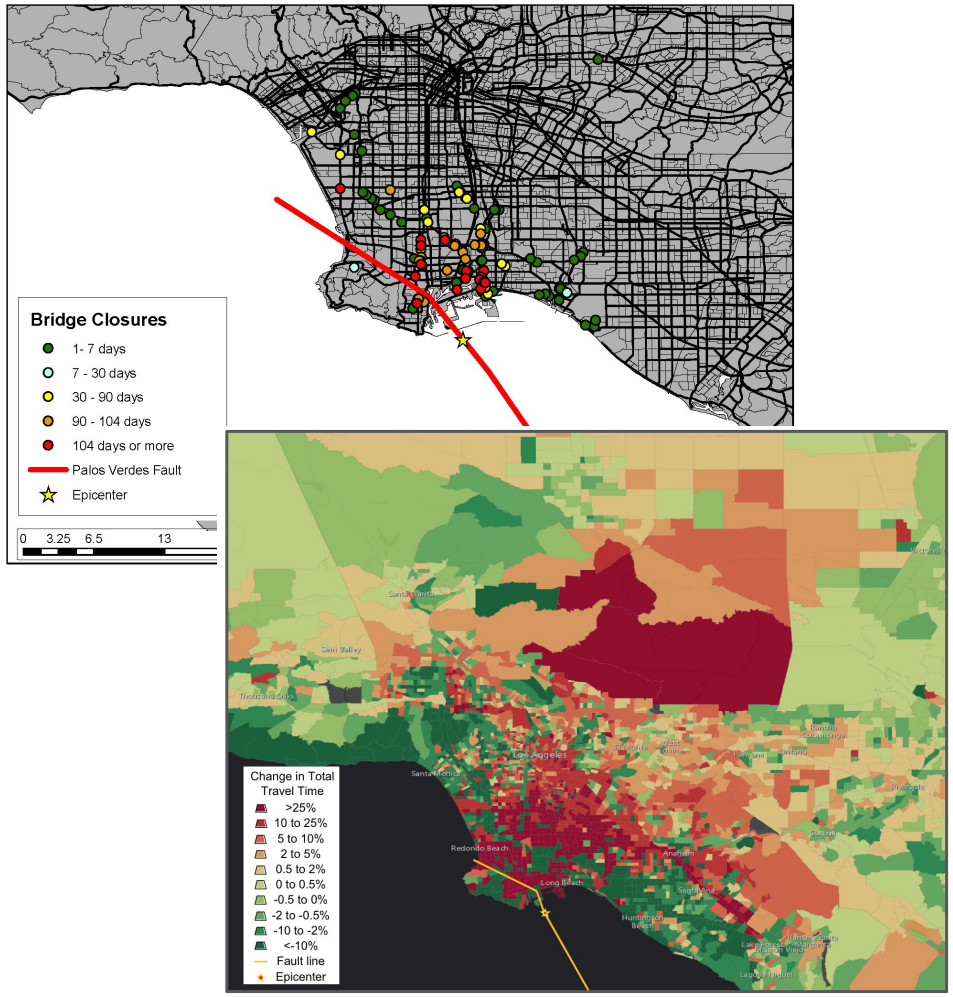
Under extreme events, the resilience of a transportation network is highly dependent on the performance of its physical components, such as roadways, bridges, and culverts.

Failure of some of these components, particularly bridges, could substantially disrupt the functioning of the network.

With the average bridge in the U.S. being 43 years old (ASCE, 2017), quantifying resiliency at network level requires detailed analyses of bridge seismic behavior.



Objectives



Develop a methodology that generates high-resolution representations of post-disaster transportation network conditions, and the consequent economic losses

As a demonstration of the methodology, post-event performance the Greater Los Angeles transportation network will be investigated for a hypothetical large scenario earthquake affecting the Ports of Los Angeles and Long Beach.

Ports of Los Angeles and Long Beach

- Are the largest container terminals in the US
- Account for 40% US imports and 25% US exports

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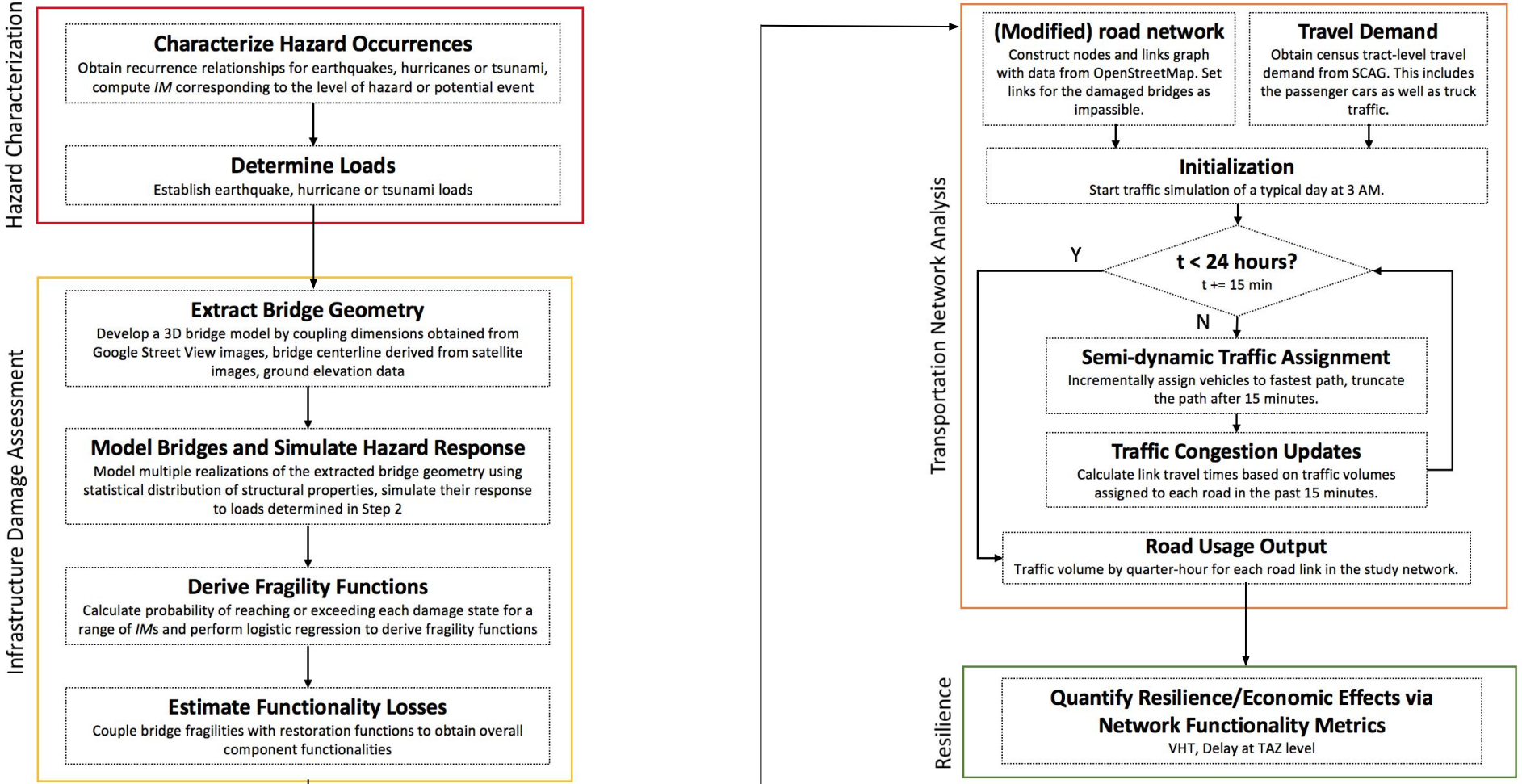
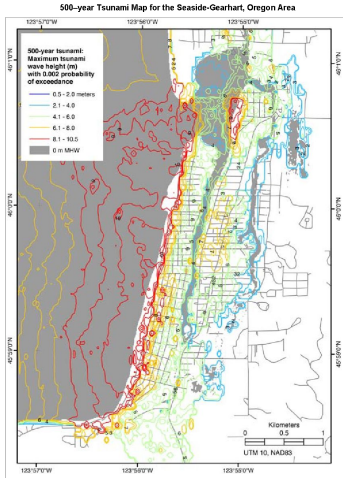
Framework: Overview



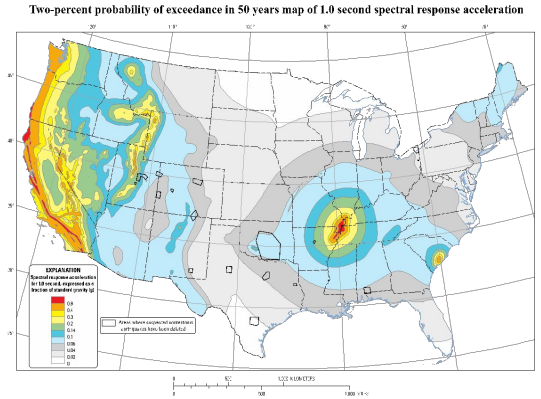
Framework: Hazard Characterization



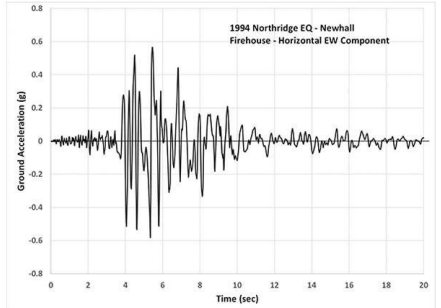
(USGS, 2013)

Characterize Hazard Occurrences
Obtain recurrence relationships for earthquake or tsunami

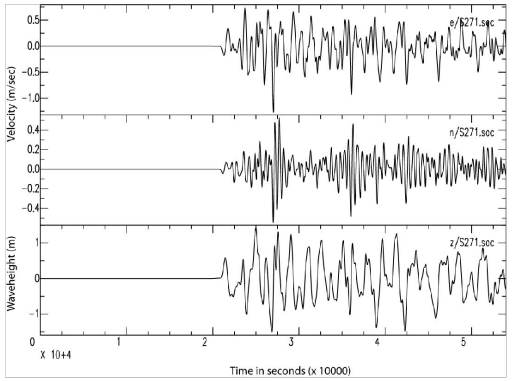
Determine Loads
Establish earthquake or tsunami loads



(USGS, 2014)

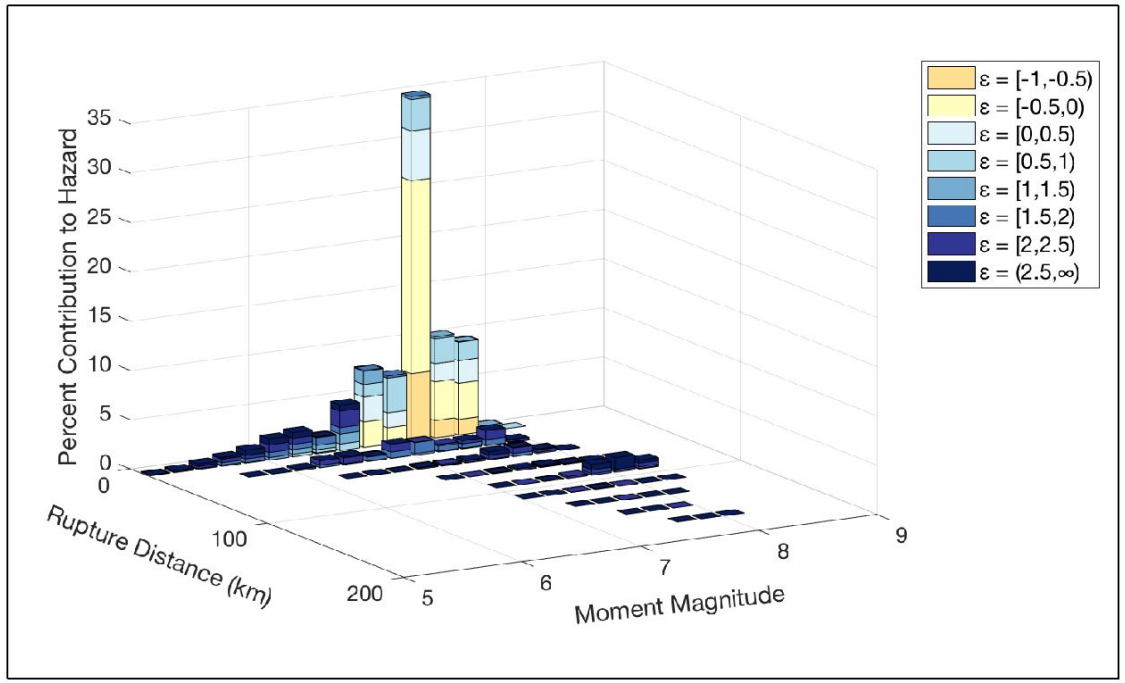


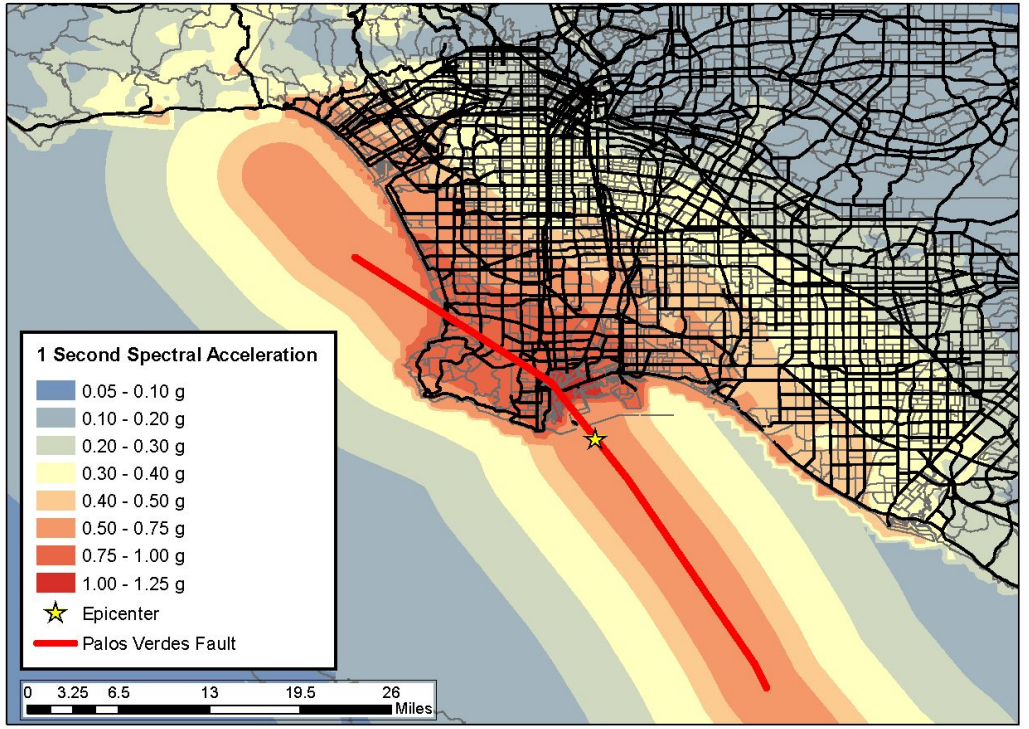
(PEER, 2013)



(USGS, 2013)

M 7.3 Palos Verdes Fault Scenario Earthquake

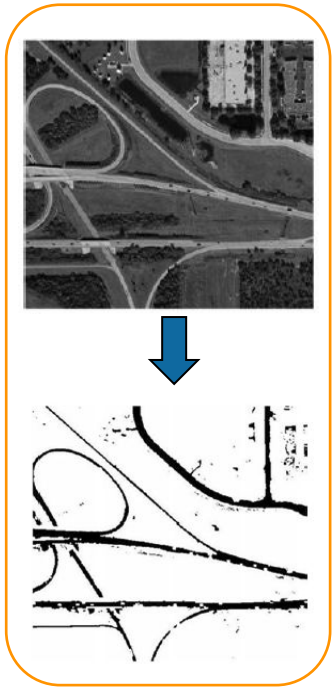


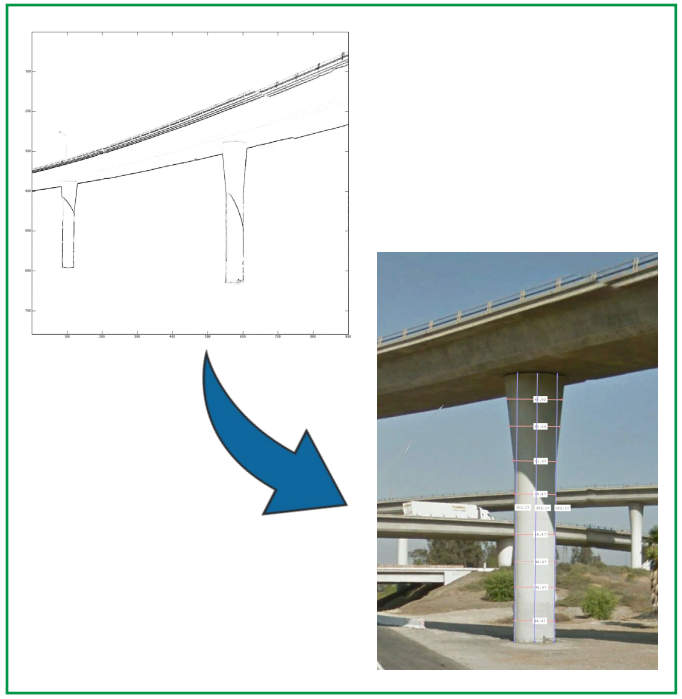


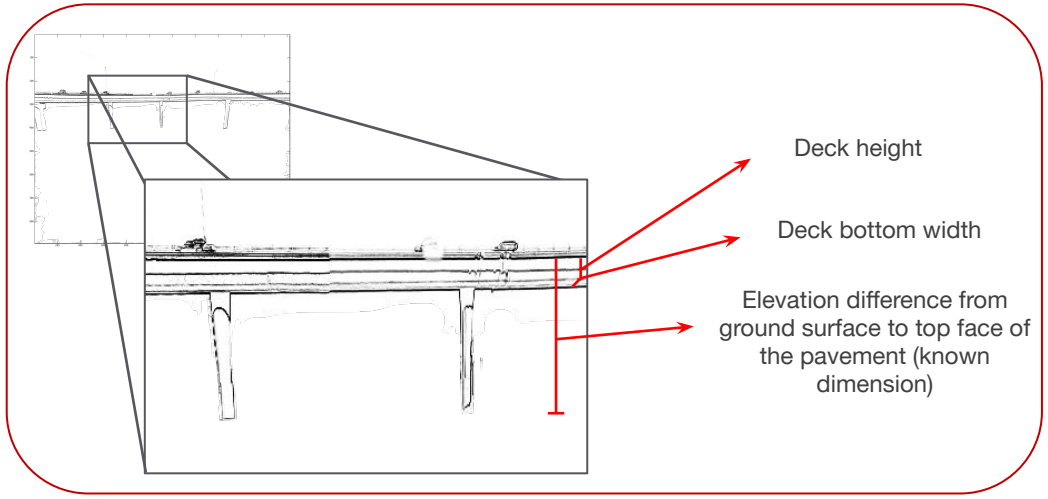
Magnitude: 7.3
Epicentral distance: 2 mi (3.25 km)

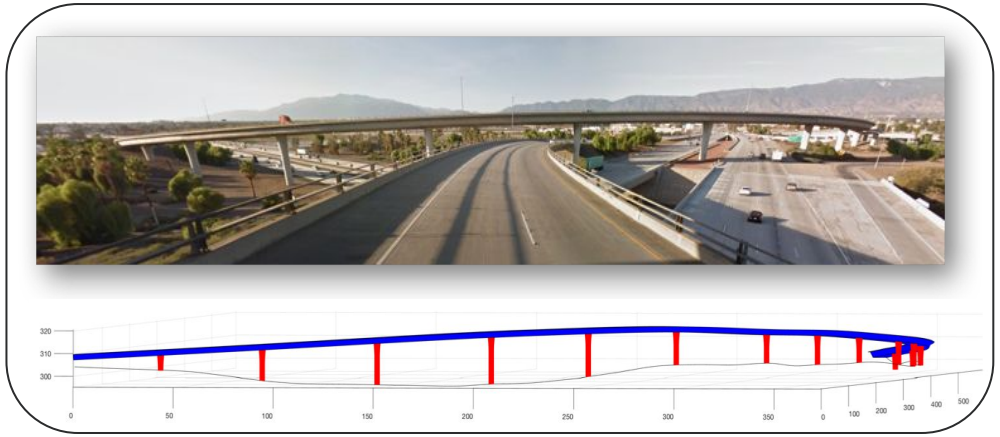
Framework: Assessment of Physical Damage

Extract Bridge Geometry
Develop a 3D bridge model by coupling dimensions obtained from Google Street View images, bridge centerline derived from satellite images/OSM, ground elevation data





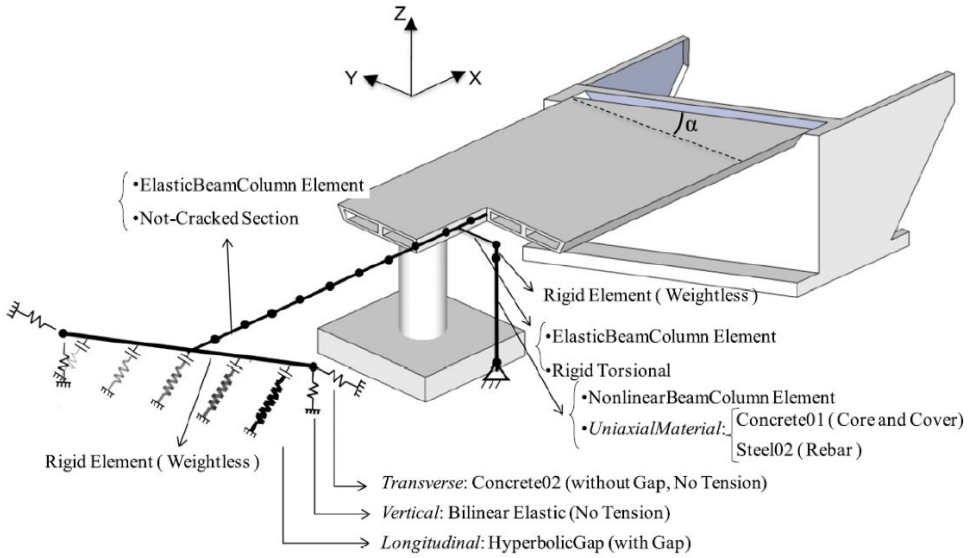


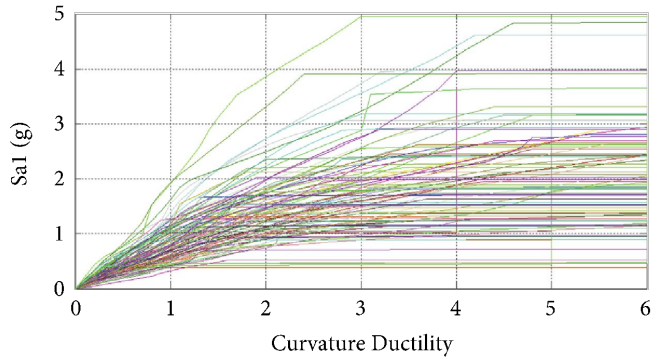


Framework: Assessment of Physical Damage

Extract Bridge Geometry
Develop a 3D bridge model by coupling dimensions obtained from Google Street View images, bridge centerline derived from satellite images/OSM, ground elevation data

Model Bridges and Simulate Hazard Response
Model multiple realizations of the extracted bridge geometry using statistical distributions of structural properties, simulate their response to the determined loads





Transverse steel reinforcement ratio					
	Distribution				
Design Era	Type	Mean	Standard Deviation	Lower Bound	Upper Bound
Pre-1971	#4 @ 12 in. irrespective of the cross-section				
Post-1971	Uniform	0.85	0.07	0.4	1.3

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Framework: Assessment of Physical Damage

Extract Bridge Geometry
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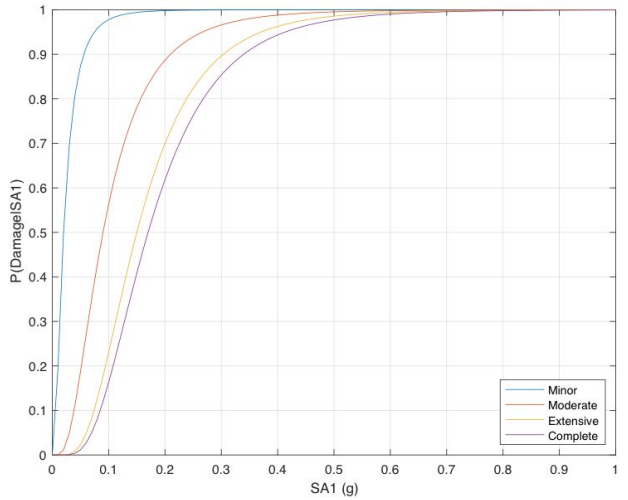
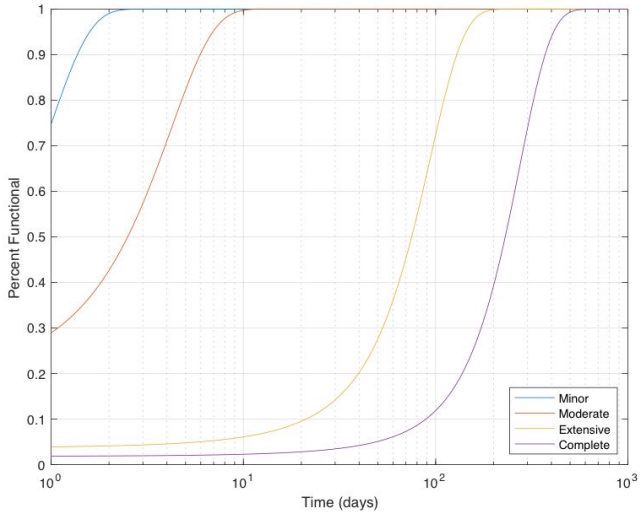
Model Bridges and Simulate Hazard Response
Model multiple realizations of the extracted bridge geometry using statistical distributions of structural properties, simulate their response to loads determined in Step 2

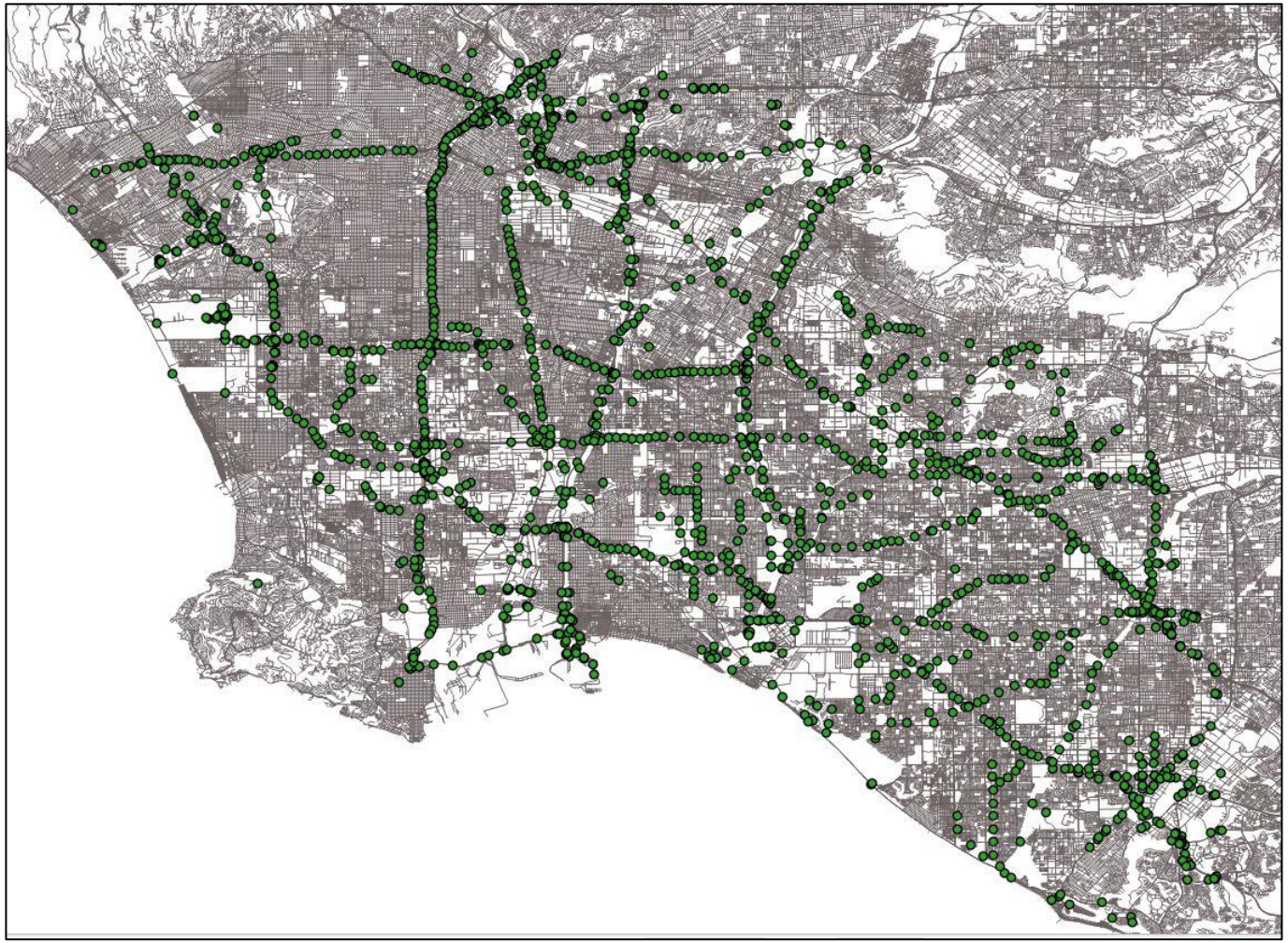
Derive Fragility Functions
Calculate probability of reaching or exceeding each damage state for a range of *IM*s and perform logistic regression to derive fragility functions

Estimate Functionality Loss
Couple bridge fragilities at the *IM* calculated *in* Step 1 with restoration functions to obtain overall bridge functionality





Bridges Modeled for This Project (1000)

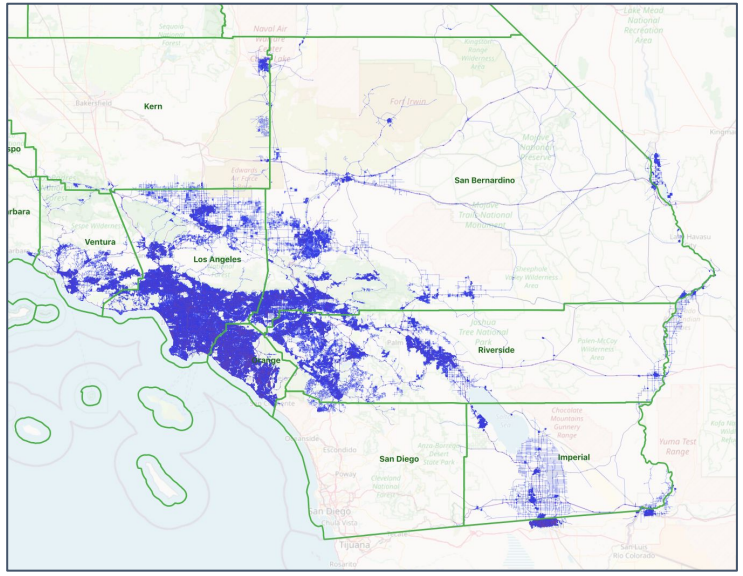


Traffic simulation: SCAG Road Network

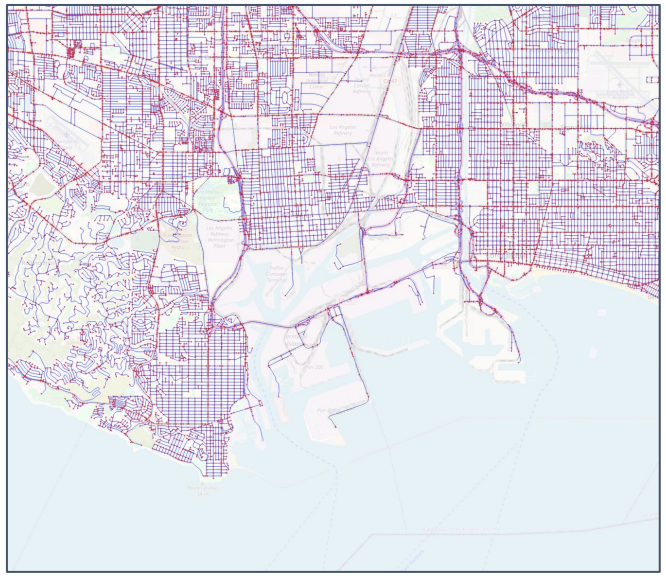
Road network is downloaded from OpenStreetMap for the six counties that comprise the SCAG region (Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura).

The network consists of 615,714 intersections (nodes) and 1,444,790 roads (edges).

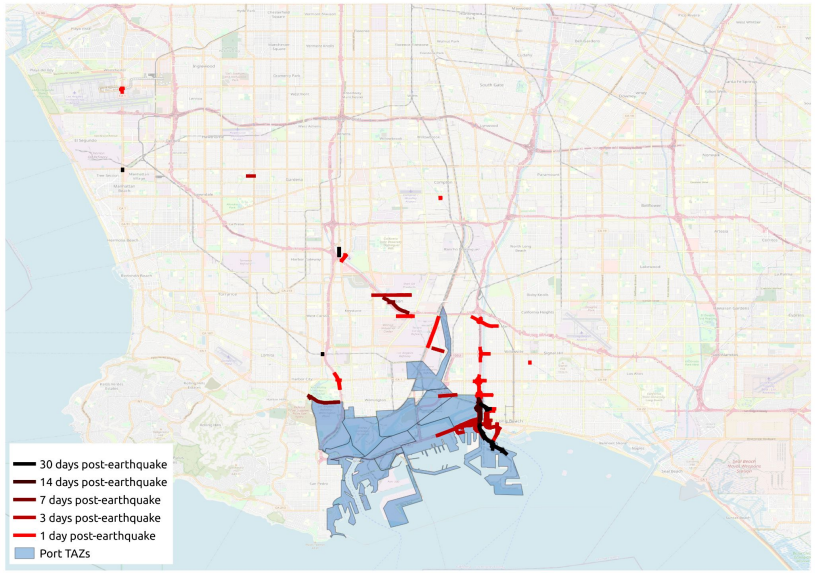
Post-earthquake bridge closures: {59, 44, 14, 10, 6} miles of roadway were closed {1, 3, 7, 14, 30} days after the earthquake



SCAG Road Network



Roads around Port of LA



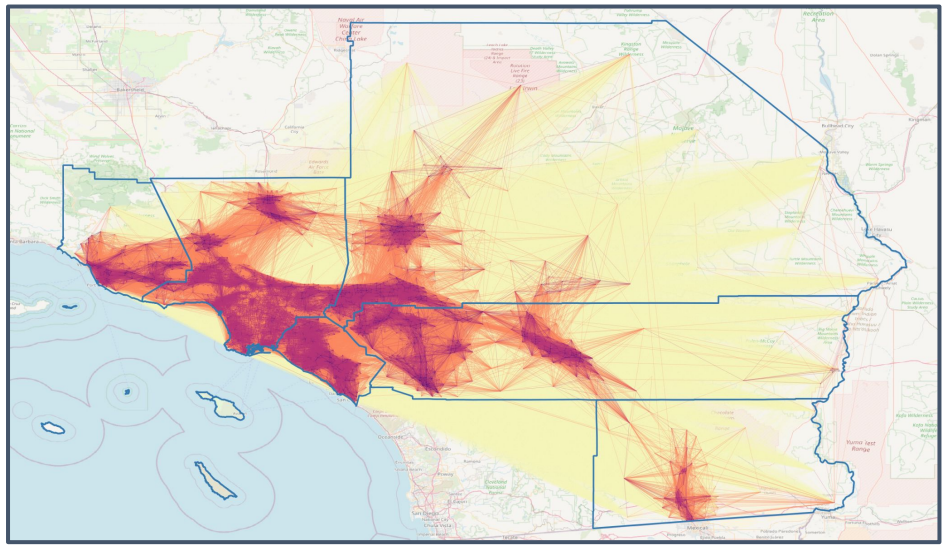
Bridge closures

Traffic Simulation: Travel Demand

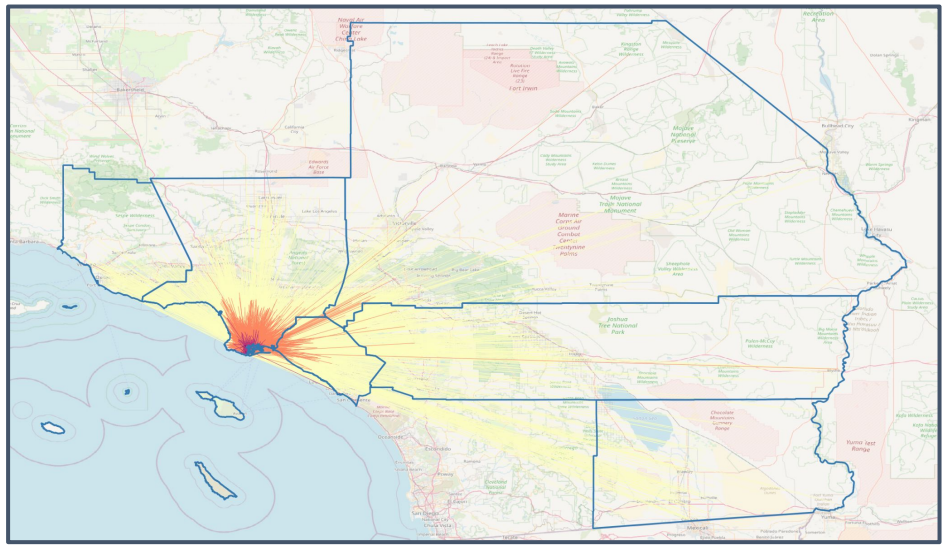
Travel demand (origin-destination flow, OD) from SCAG were processed.

Left: A subset of the trips within the SCAG area: # totals trips considered = 10,680,134

Right: Trips from the ports to other destinations in the SCAG area. # trips = 200,000 ~= daily port traffic.

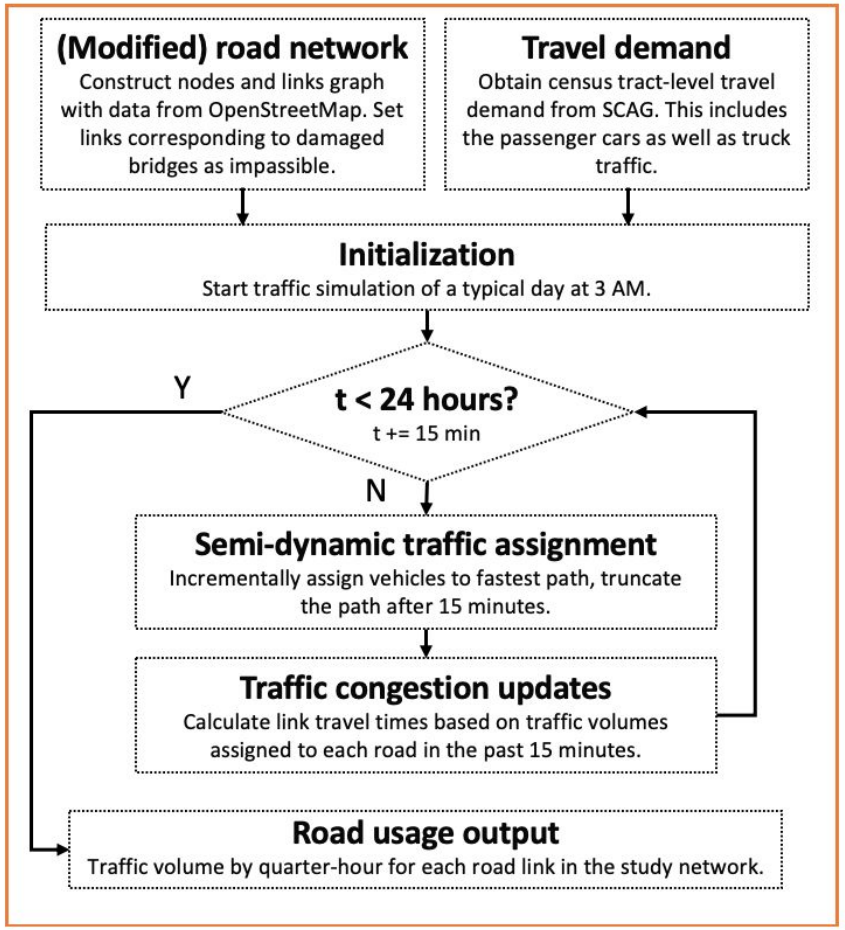


SCAG traffic: ~10.6 million trips



Port traffic: 0.2 million trips

Methodology



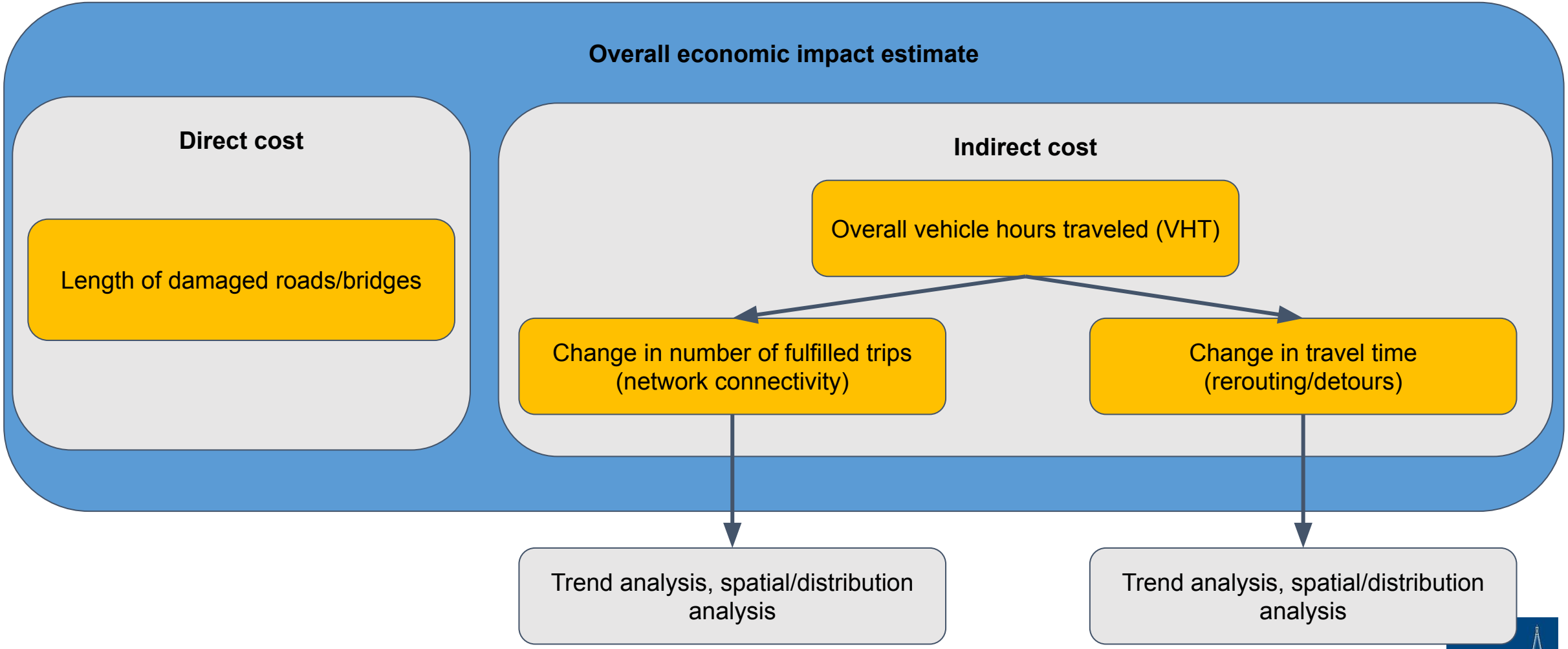
Semi-dynamic traffic assignment model used to compute for traffic volume on roads before and after bridge closures.

Travel time update:

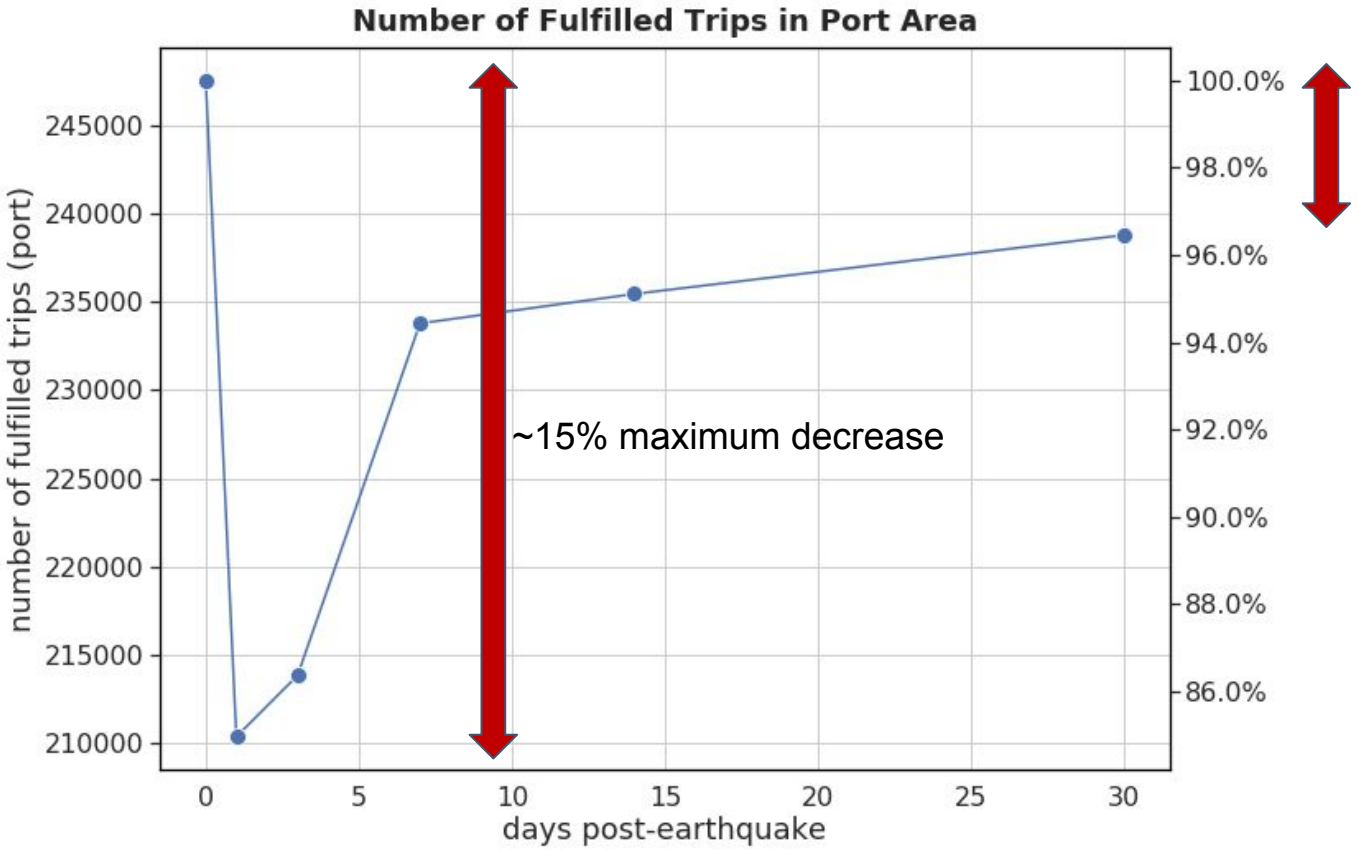
$$\hat{t} = t_0 \left(1 + a \cdot \left(\frac{q}{q_{\max}} \right)^b \right)$$

- Vehicles are assumed to choose fastest path under current road closure and traffic congestion status.
- Trucks are restricted from using residential roads

Impact measurements

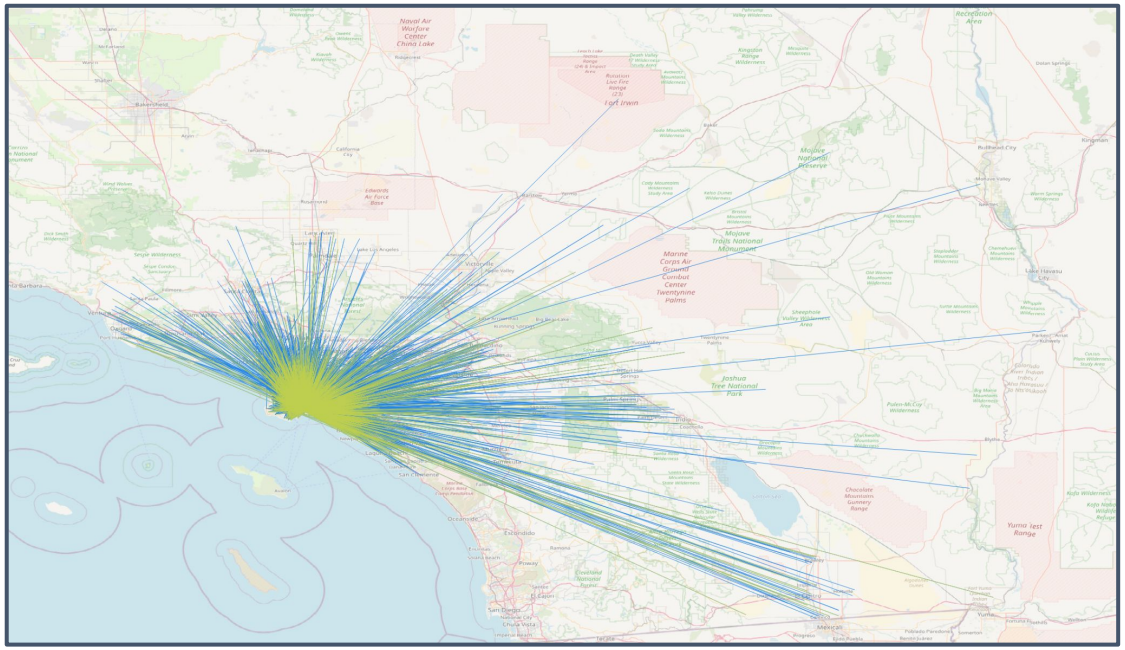


Unfulfilled trips

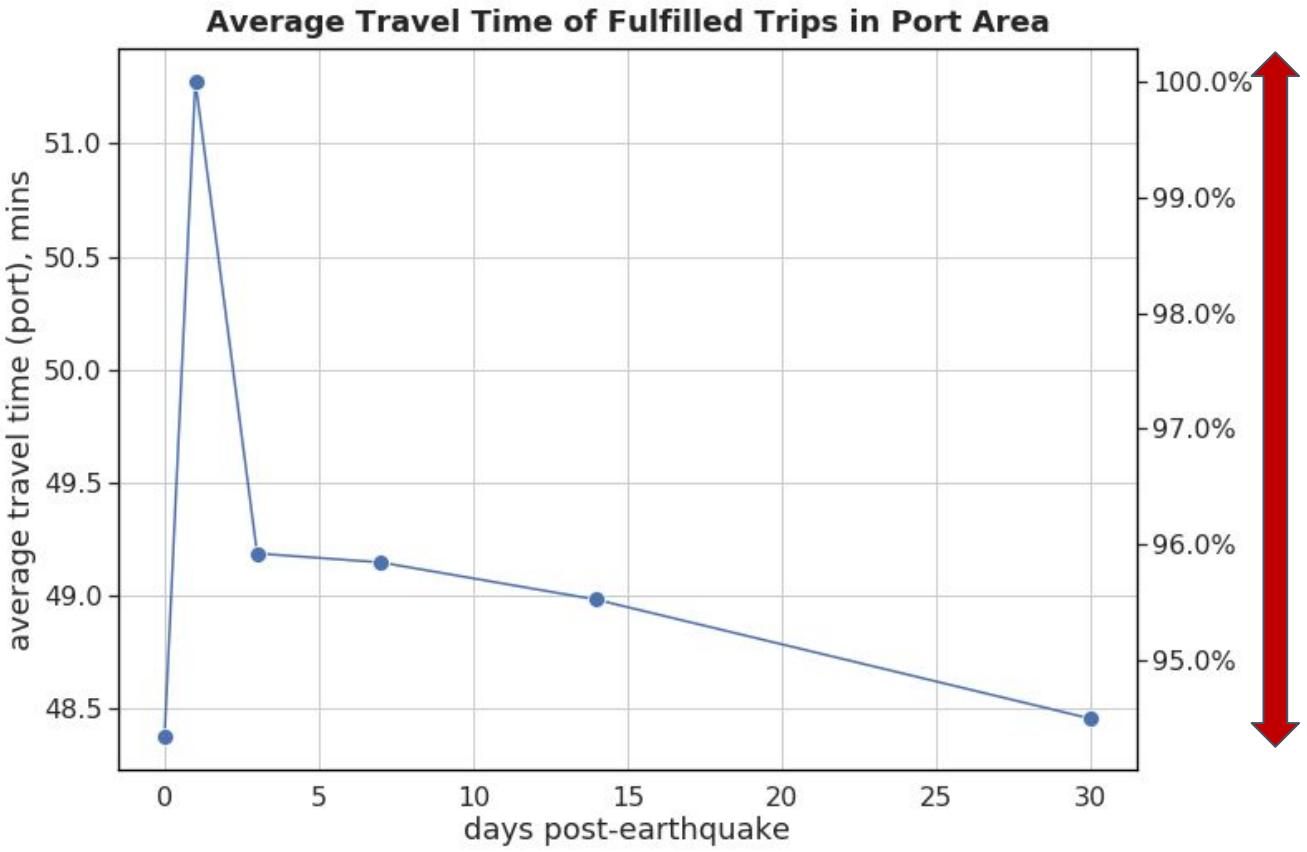


4% decrease

Unfulfilled trips a day after the earthquake (blue: overall; green: port)

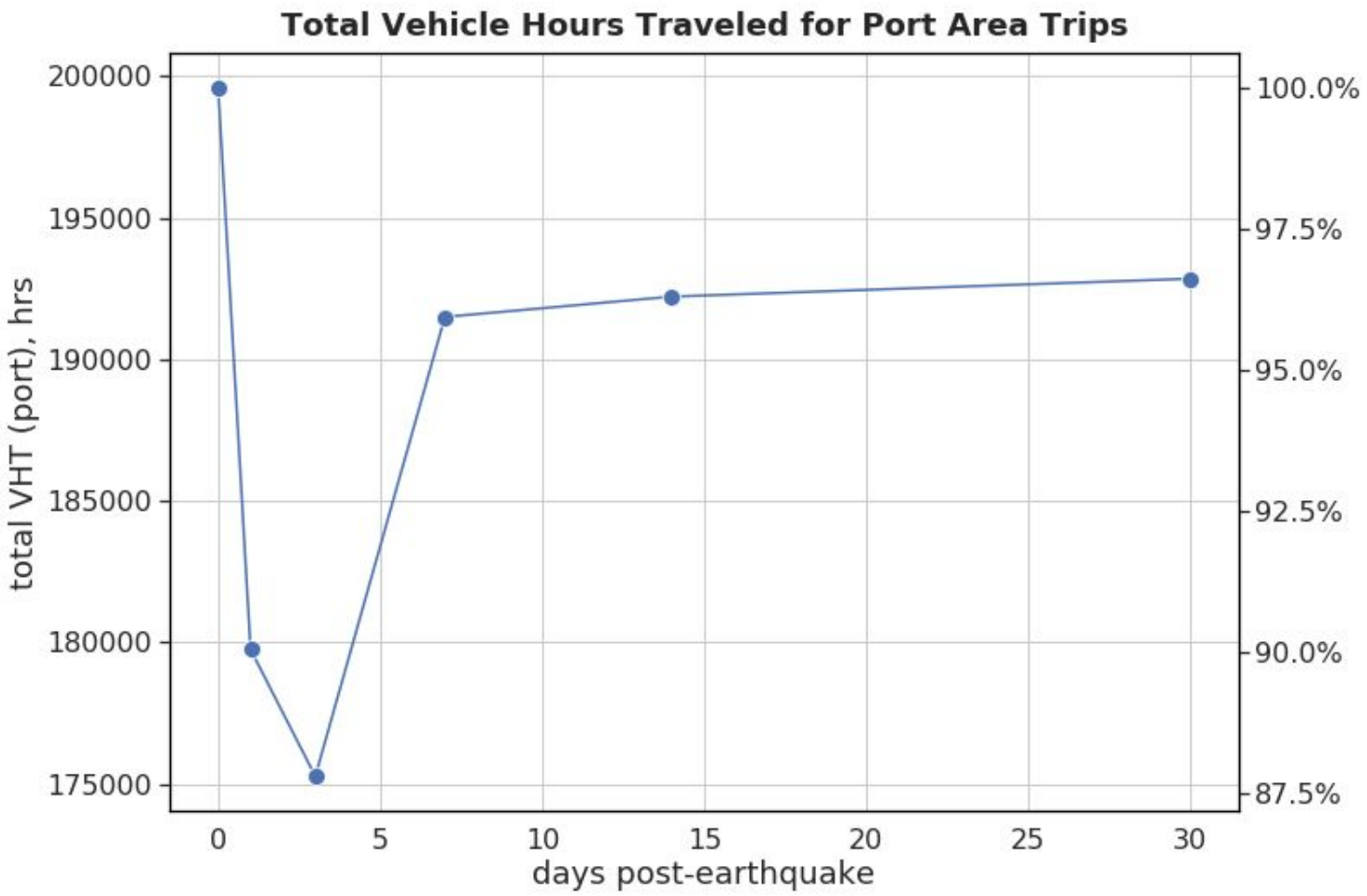


Travel time



~6% maximum increase

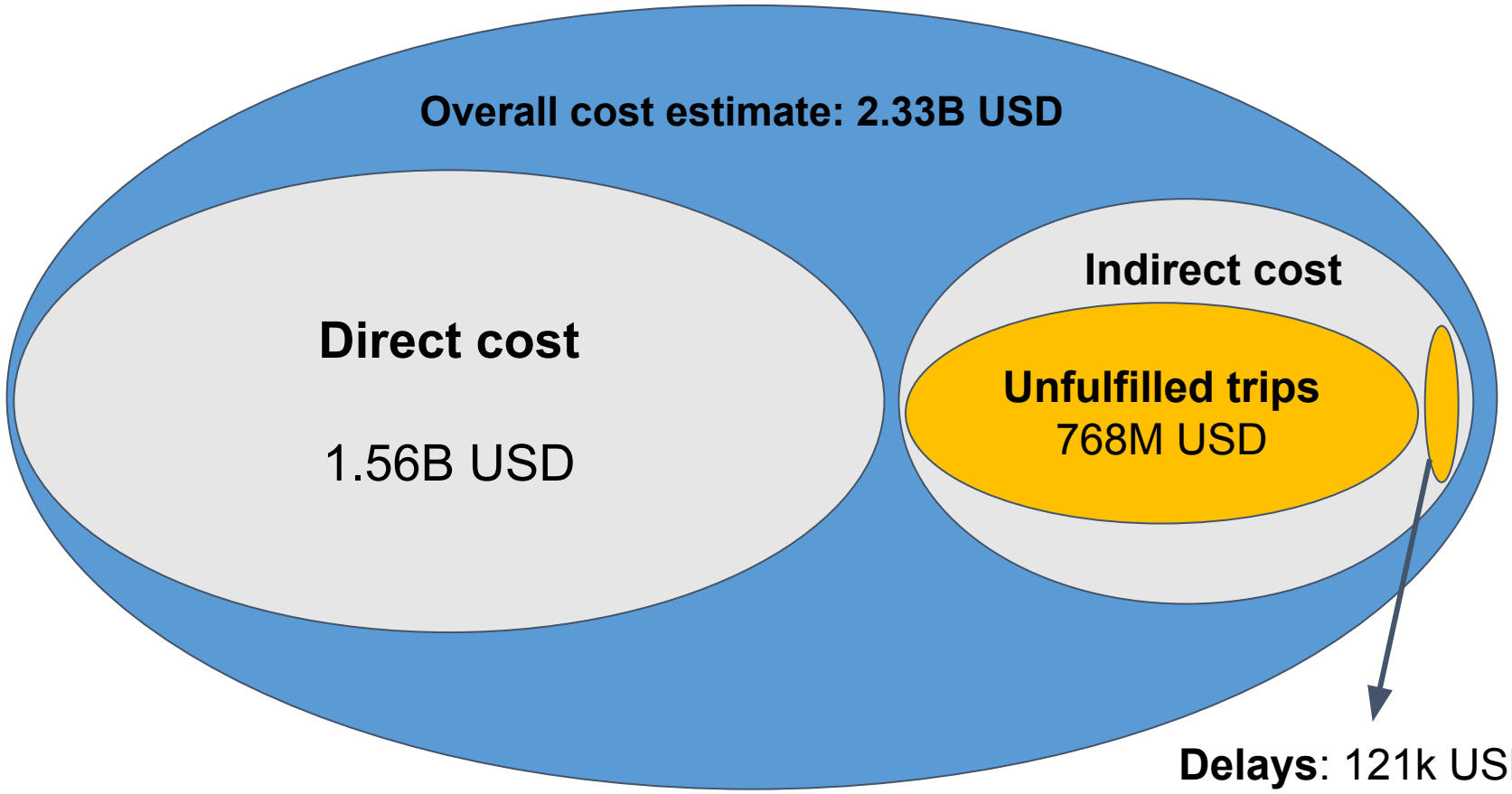
Vehicle hours traveled (VHT)



plateaus at ~4% decrease

12.5% maximum decrease

Economic impact assessment



less than 1% of SCAG GDP

SCAG GDP:
1.2T USD

Caltrans retrofit budget?

Bridge closure costs versus bridge repair budgets

- 2022 California Bridge Formula Program budget: 575M USD (5-year program budget total: 4.2B USD; significantly below total repair cost estimated at 11.7B USD)
- Our study results: 1.56B USD direct cost and 768M USD indirect cost
  - estimated indirect cost (cost of externalities shouldered by individuals) post-earthquake shows that total costs increase by almost 50% without proper mitigation

Discussion

- Port area is disproportionately impacted: accounts for 50% of all unfulfilled trips, 62% of total indirect cost
- Lost demand dominates indirect cost over delays; road network connectivity (particularly of port island to mainland LA) is key issue
- Almost 50% of post-earthquake impact costs can be avoided with proper mitigation
- Future work: include freight impacts more explicitly

Thank you