Socioeconomic Dimensions of Resilience to Seaport and Highway Transportation Network Disruptions

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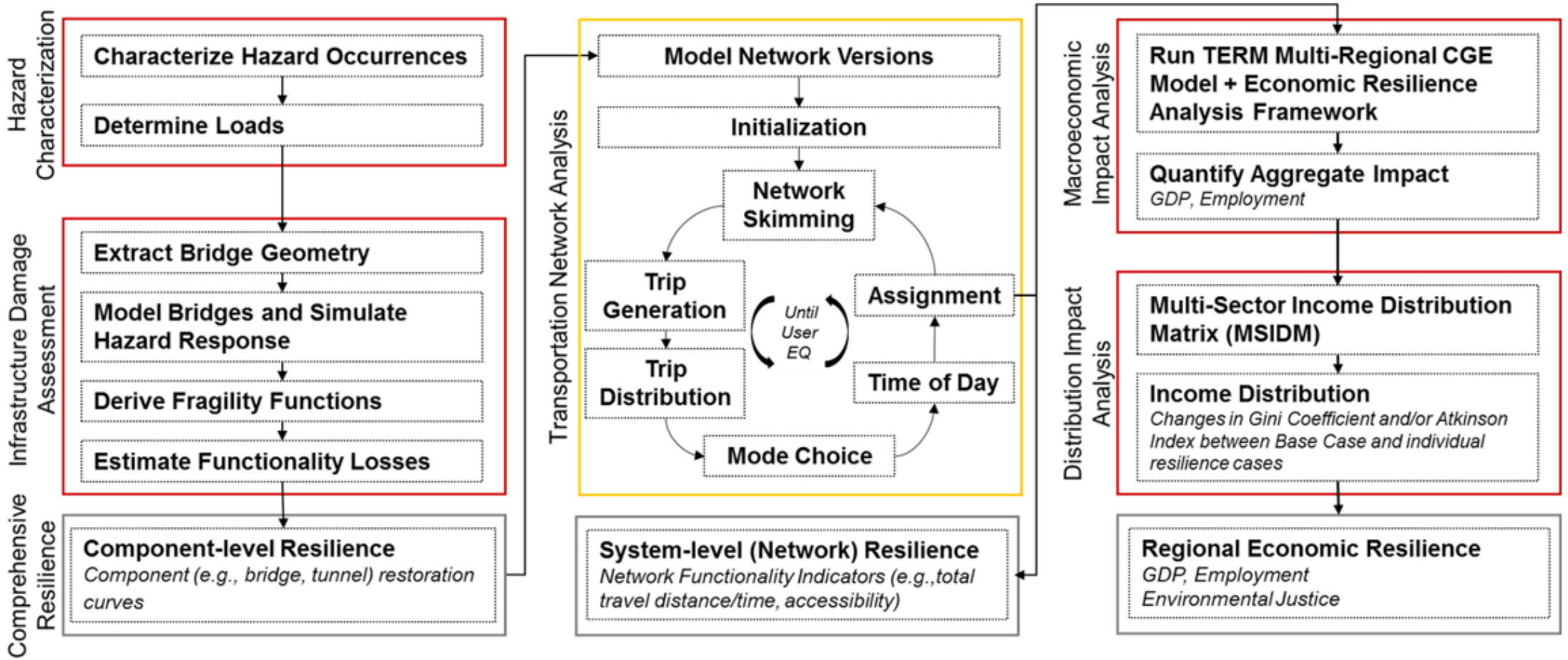
Introduction

- Economic impacts of seaport and highway transportation network disruptions can be extensive well beyond on-site operations through supply-chain effects.

- Research gaps: 1) resilience considerations; 2) spatial distribution and networked nature of transportation systems; 3) income distribution impacts

- Objective of this study:
  - Develop a synergetic approach linking a regional transportation model, a multi-regional computable general equilibrium (CGE) model, and a multi-sector income distribution matrix to analyze socioeconomic impacts of port and transportation network disruptions and effectiveness of resilience tactics
  - Apply the integrated transportation and socioeconomic analysis model to a simulated earthquake scenario

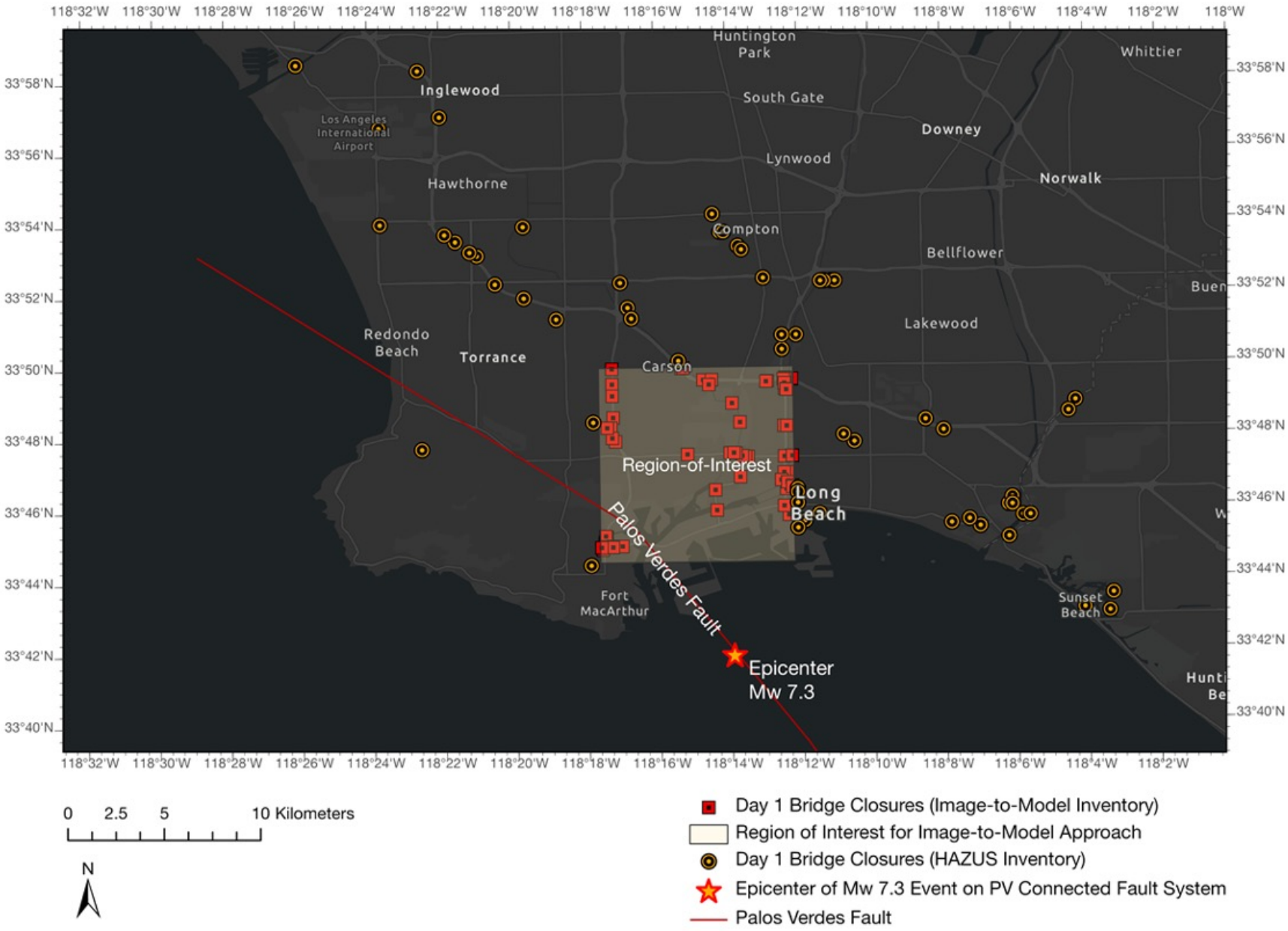
Comprehensive Assessment of Transportation Resilience in Metropolitan Areas

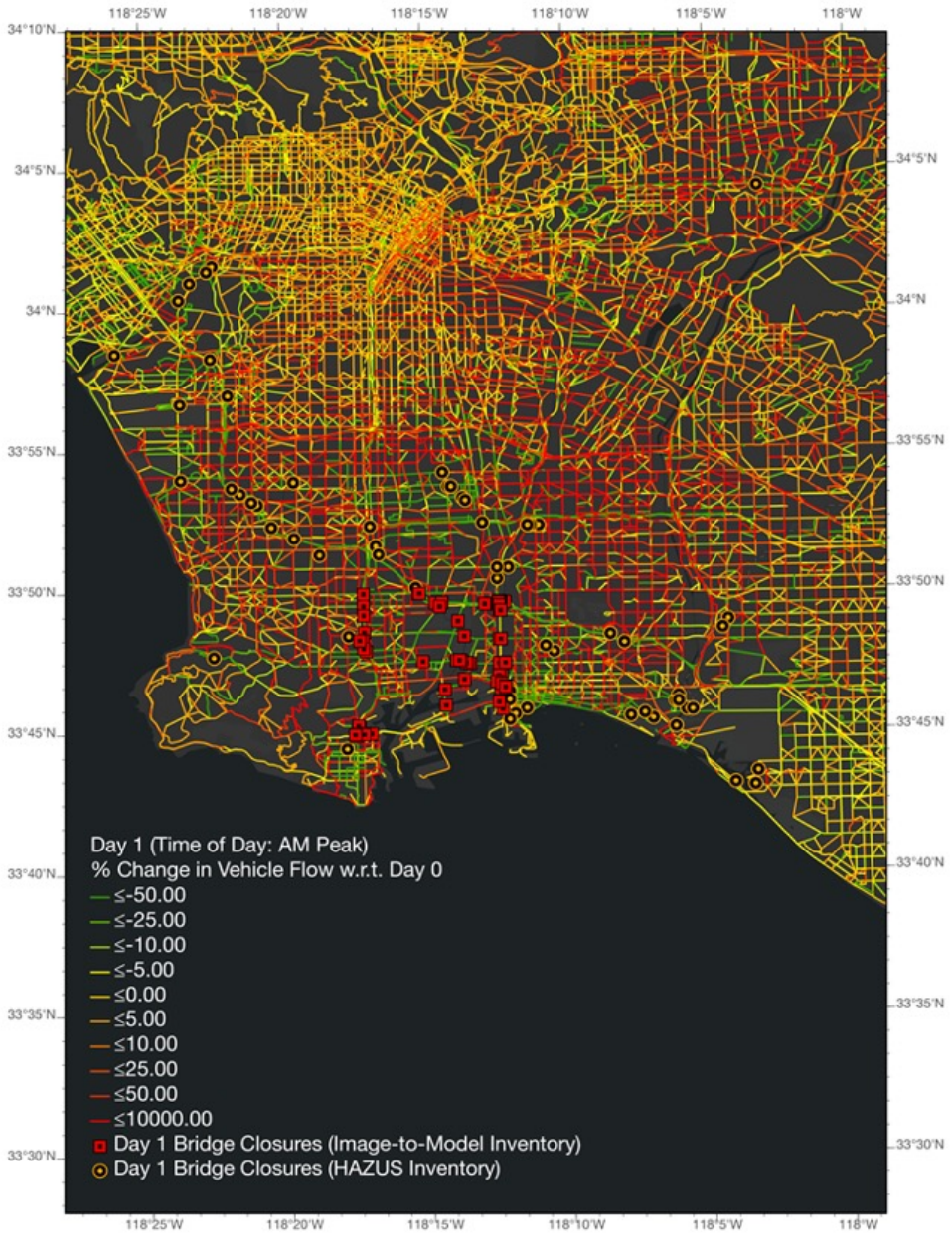


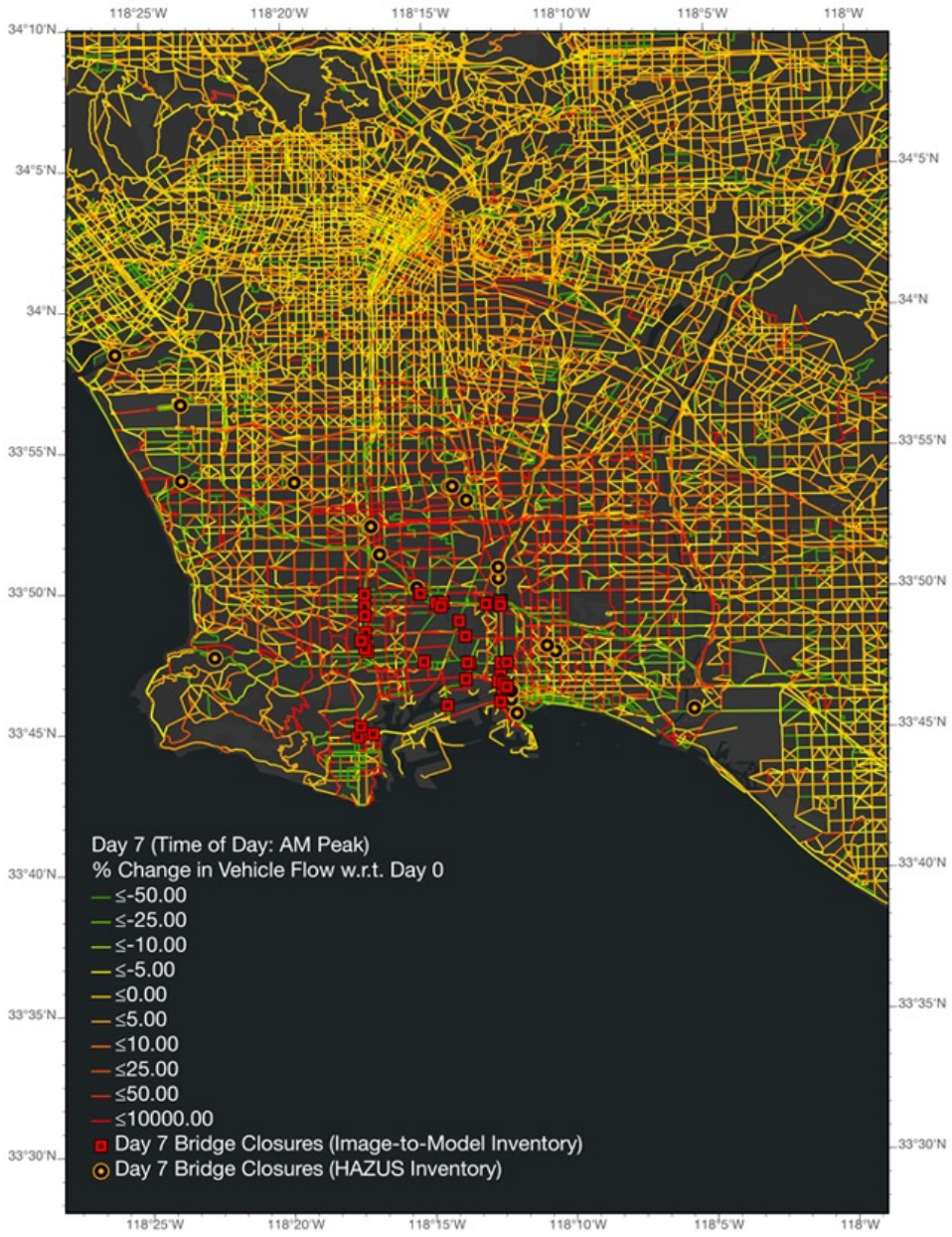
Case Study

Bridge Closures

(Day 1)




118°25'W
118°20'W
118°15'W
118°10'W
118°5'W
118°W
34°10'N
34°5'N
34°N
33°55'N
33°50'N
33°45'N
33°40'N
33°35'N
33°30'N
Day 1 (Time of Day: AM Peak)
% Change in Vehicle Flow w.r.t. Day 0
≤-50.00
≤-25.00
≤-10.00
≤-5.00
≤0.00
≤5.00
≤10.00
≤25.00
≤50.00
≤10000.00
Day 1 Bridge Closures (Image-to-Model Inventory)
Day 1 Bridge Closures (HAZUS Inventory)


118°25'W
118°20'W
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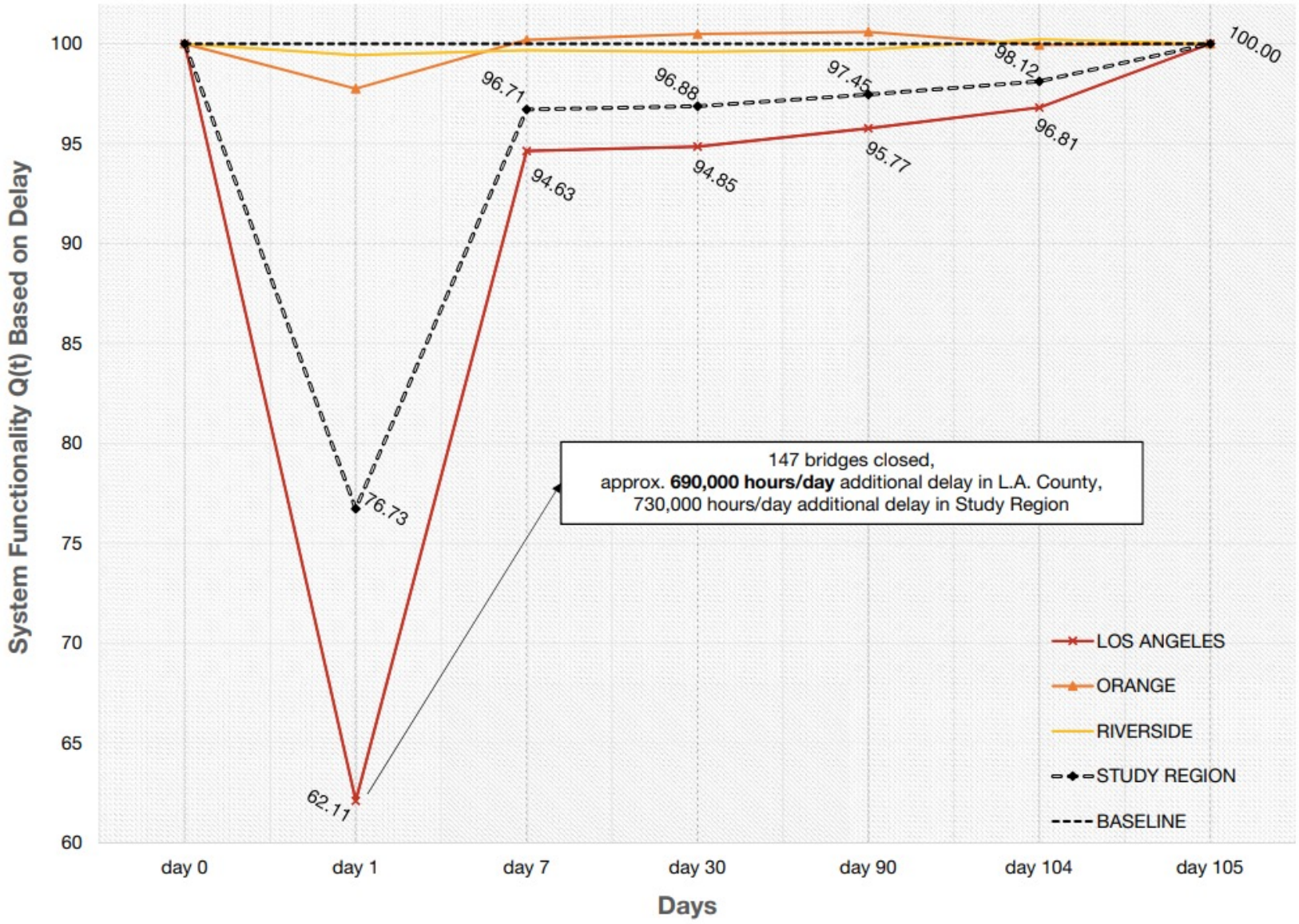
34°10'N
34°5'N
34°N
33°55'N
33°50'N
33°45'N
33°40'N
33°35'N
33°30'N
Day 7 (Time of Day: AM Peak)
% Change in Vehicle Flow w.r.t. Day 0
≤-50.00
≤-25.00
≤-10.00
≤-5.00
≤0.00
≤5.00
≤10.00
≤25.00
≤50.00
≤10000.00
Day 7 Bridge Closures (Image-to-Model Inventory)
Day 7 Bridge Closures (HAZUS Inventory)

Case Study
System Level
Resilience
(Delay)



Economic Resilience – Basic Considerations

- Static:
  - General Definition: Ability of a system to *maintain function* when shocked.
  - Econ Definition: *Efficient use of remaining resources* at a given point in time to produce as much as possible.
- Dynamic
  - General Definition: Ability of a system to *recover*.
  - Econ Definition: *Efficient* use of resources *over time* for investment in repair and reconstruction, including expediting the process & adapting to change.

- *Metric*: *averted losses as % of potential losses*

Economic Resilience Tactics to Port and Transportation Network Disruptions

Supplier-Side Resilience Options	Customer-Side Resilience Options
Excess capacity. Utilization of unused capacity at undamaged terminals	**Use of inventories**. Stockpiling critical inputs for the production of goods and services by firms
Cargo prioritization. Altering schedules for unloading or loading based on the characteristics or value of the cargo	**Conservation**. Finding ways to utilize less of disrupted imported goods in production processes
Ship re-routing. Sending ships to other ports	**Input substitution**. Utilizing similar goods in the production process to those whose production has been disrupted
Export diversion for import use. Sequestering goods intended for export to substitute for unavailability of imports or domestically-produced goods	**Import substitution**. Bringing in goods and services in short supply from outside the region through land routes
Effective management. Improvements in decision-making and expertise that enhance functionality	**Production relocation**. Shifting production to branch plants
Production recapture. Working extra shifts or over-time to clear up backlog of vessels after resumption of port operation	**Production recapture**. Making up lost production by working extra shifts/overtime after port re-opens
Effective road infrastructure asset management. Improvements in decision-making and expertise that enhance functionality and recovery	**Effective travel demand management**. Establishing measures to decrease travel demand during recovery

TERM CGE Model

- Bottom-up multi-regional CGE model (Monash U.)
- Based on detailed regional & sectoral accounts
- Consists of 4 regions: 3-County LA Region, 9-County Bay Area, Rest of CA, and Rest of U.S.
- Divides the economy into 97 sectors
- CES production functions (allows for substitution)
- Explicit trade and transport margins

Simulation Results – Combined Disruptions/Damages

(in millions 2019 dollars and percent reduction from pre-disaster levels)

	LA Metro	SF Metro	Rest of CA	Rest of US	US Total	Loss Reduction Potential (for LA)	Loss Reduction Potential (for US)
Base Case (no resilience)	-24,208	-828	-855	-4,296	-30,187		
	-3.00%	-0.17%	-0.15%	-0.03%	-0.22%		
Combined Resilience Case	-14,200	-12	-167	1,571	-12,808	41.34%	57.57%
	-1.76%	0.00%	-0.03%	0.01%	-0.09%		

Income Distribution Impacts

- Compare Gini coefficients between the scenario cases and baseline level

Disruption Type	Baseline	Scenario Gini Coefficient	Change in Gini Coefficient
Port Disruption_Base Case	0.465478	0.465614	0.000136
Transportation Cost Increase_Base Case	0.465478	0.465478	0.000000
Building Damage_Base Case	0.465478	0.463904	-0.001574
Combined Disruptions_Base Case	0.465478	0.464041	-0.001438
Port Disruption_Resilience Case	0.465478	0.465473	-0.000006
Transportation Cost Increase_Resilience Case	0.465478	0.465478	0.000000
Building Damage_Resilience Case	0.465478	0.464243	-0.001235
Combined Disruptions_Resilience Case	0.465478	0.464238	-0.001240

- Income losses born disproportionately by lower-income groups in Port Disruption Base Case
- Port resilience tactics help reduce income inequality
- Income losses born disproportionately by middle- & higher-income groups in the other two cases.

Conclusion

- Develop and apply an integrated transportation-socioeconomic impact model to analyze aggregate economic and income distributional impacts of port and highway transportation disruptions.
- Resilience tactics can potentially reduce GDP losses by 41% and 58% at the regional and national levels, respectively.
- Effective port resilience tactics: ship-rerouting, inventory use, input substitution, and production recapture.
- Income losses from port disruptions are born slightly disproportionately by lower- and middle-income groups; the distributional impacts are the opposite for transportation cost increase and building stock damages.
- Port resilience tactics help reduce the inequality in income distribution.

Questions and Comments?

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