Assessing Network Connectivity, Vulnerability and Resilience

A Case Study from Southern California

presented to
Modeling Mobility 2025

presented by
Cambridge Systematics, Inc.
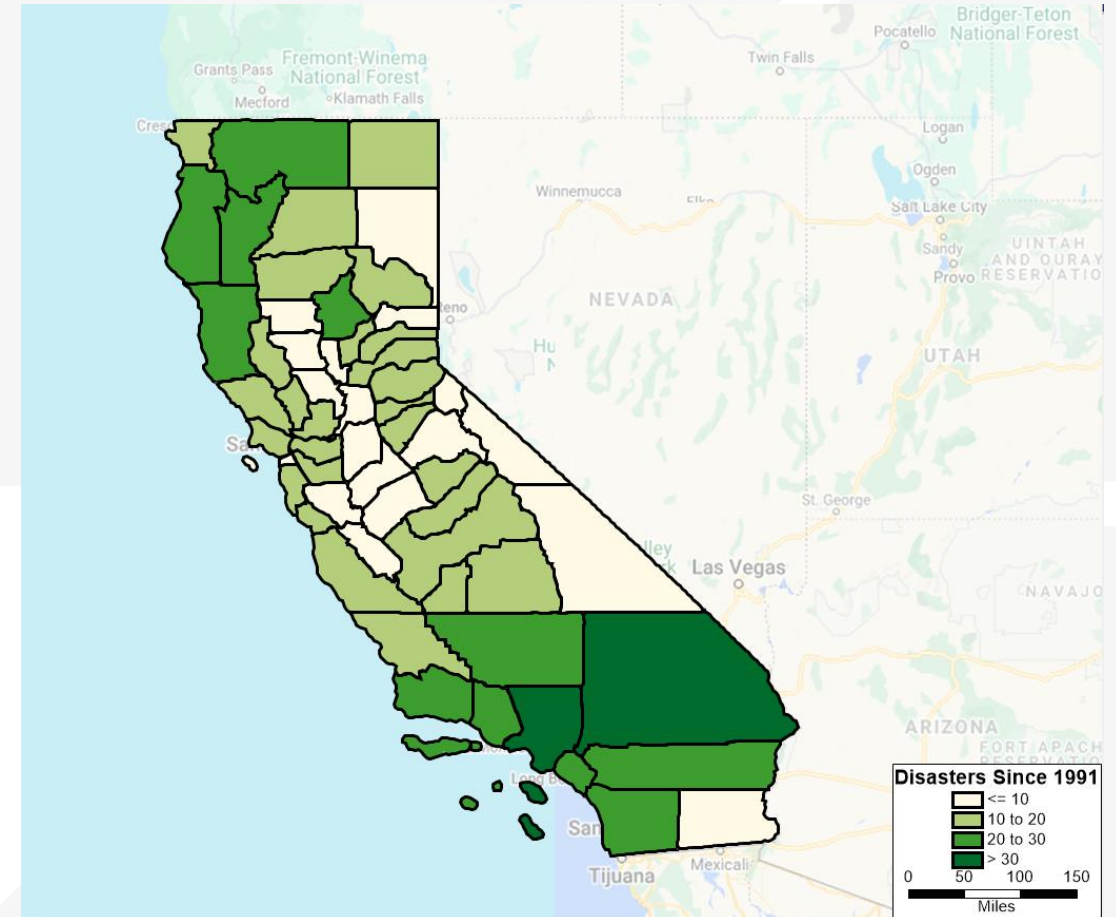*Zeina Wafa*

September 15th , 2025

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Agenda

➤ Introduction

➤ Compliance Assessments
  » Intersection Density
  » Distance to Exits and Shelters
  » Emergency Response Times
  » AB 747: Average Evacuation Time
  » SB 99: Stranded Zones Analysis

➤ Regional Evacuation Analyses

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Introduction

➤ 197 natural disaster events in California since October 1991, impacting all 58 counties.

➤ San Bernardino County Fire Department 22nd busiest in the nation in 2021.

Disasters Since 1991
<= 10
10 to 20
20 to 30
> 30

0   50   100   150
Miles

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Introduction

Senate Bill 99

Mandates that cities and counties review their Safety Elements to identify residential developments in hazard zones with only one evacuation route.
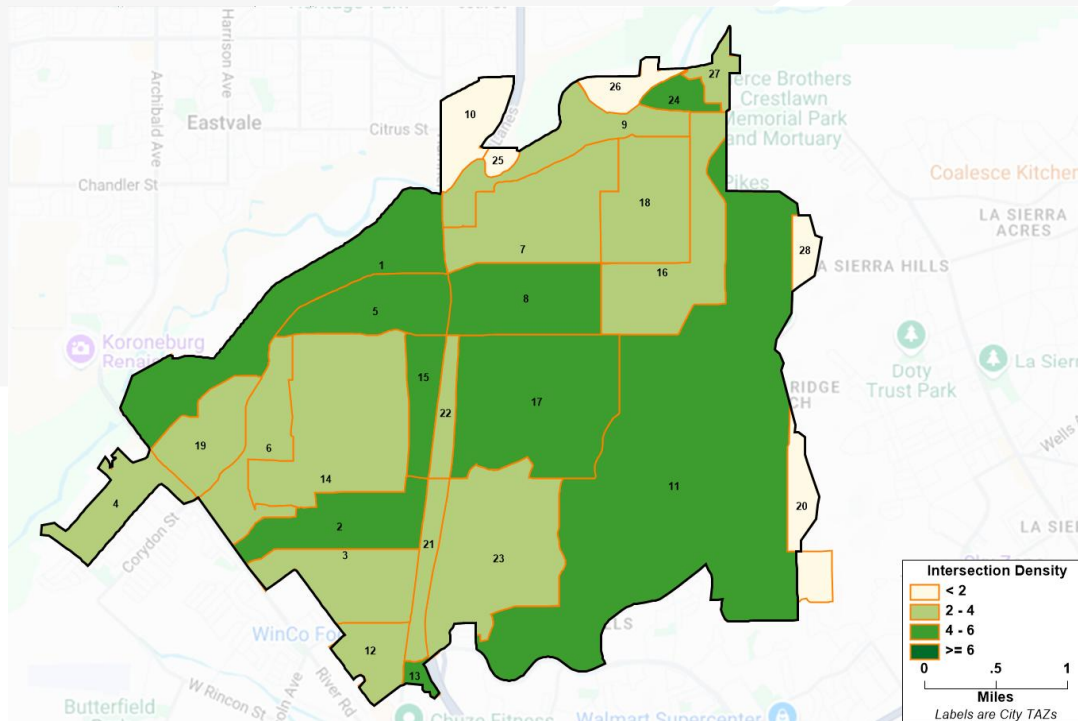
Assembly Bill 747

Requires local jurisdictions to identify and analyze the capacity, safety, and viability of evacuation routes under potential emergency scenarios, like wildfires or tsunamis.

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Introduction

- San Bernardino County Emergency Evacuation and Network Resilience Study

- Funded by the FY 2023-24 Caltrans Sustainable Transportation Planning Grant Program

- Resilience planning efforts are important because "…existing hazards, such as landslides, flooding, and wildfire risks, and are expected to strain the transportation networks and communities of both San Bernardino and Riverside Counties."
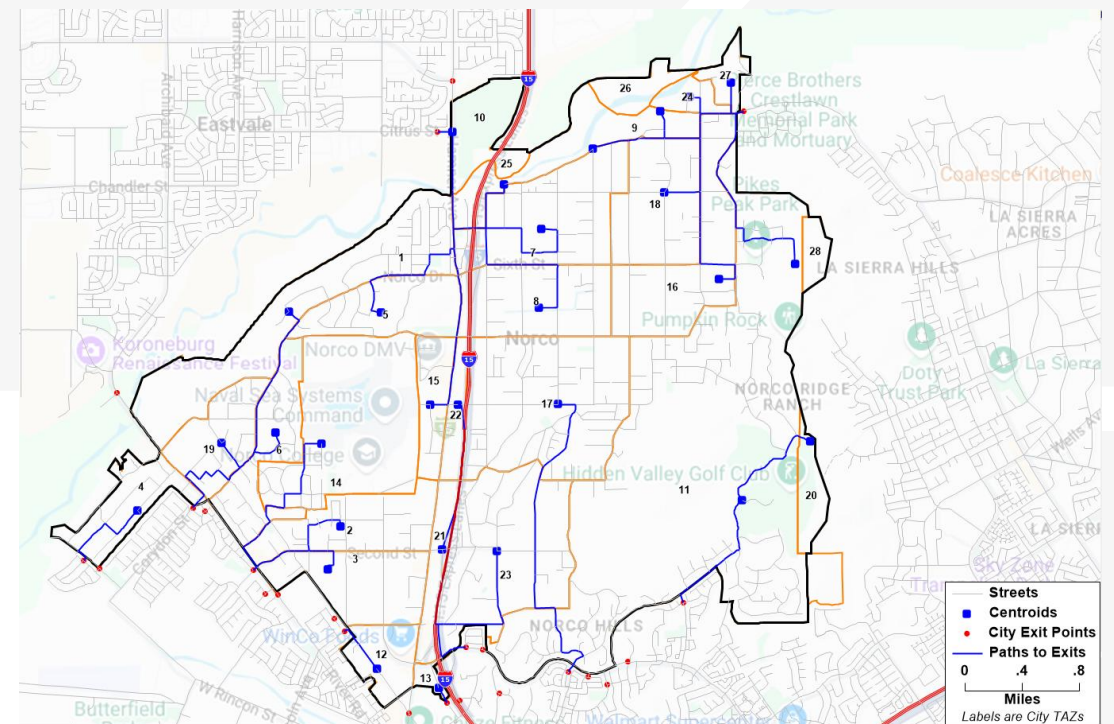
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Compliance Assessments

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Intersection Density

Intersection Density
- < 2
- 2 - 4
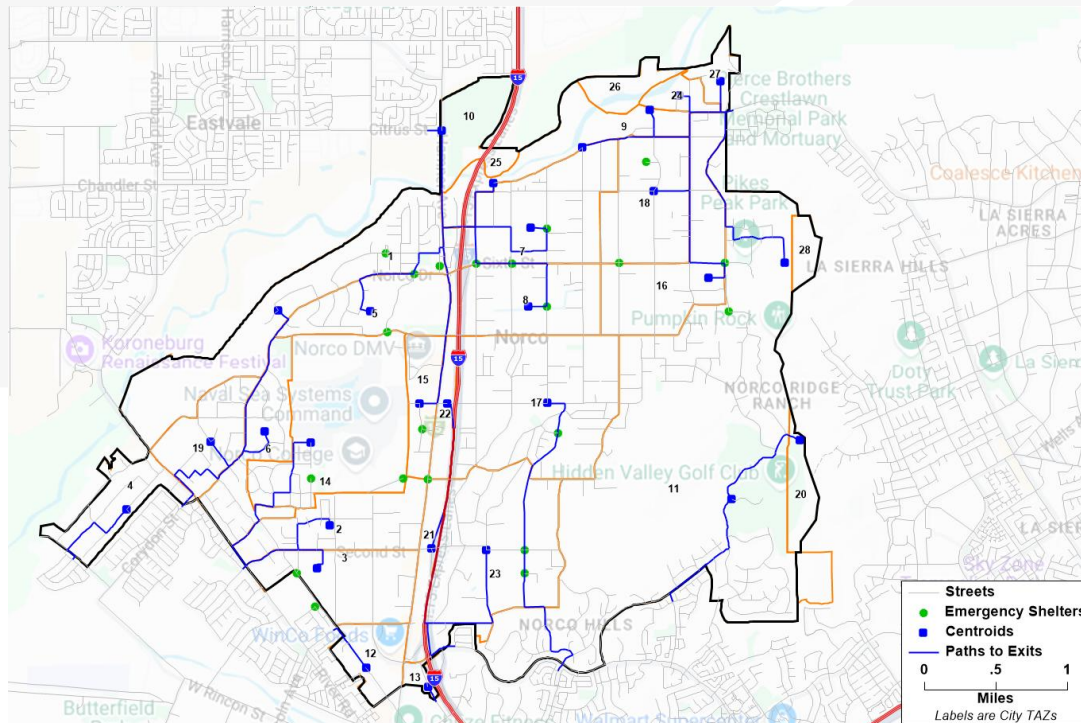- 4 - 6
- >= 6

0   .5   1
Miles
Labels are City TAZs

➤ Measure of network connectivity.

➤ Requires a network more detailed than a model network.

➤ Can be measured as number of intersections per mile of street network for each TAZ.

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Distance to Exits

- Identifies the shortest distance from every TAZ centroid to exit city boundaries.

- Requires a network more detailed than a model network.

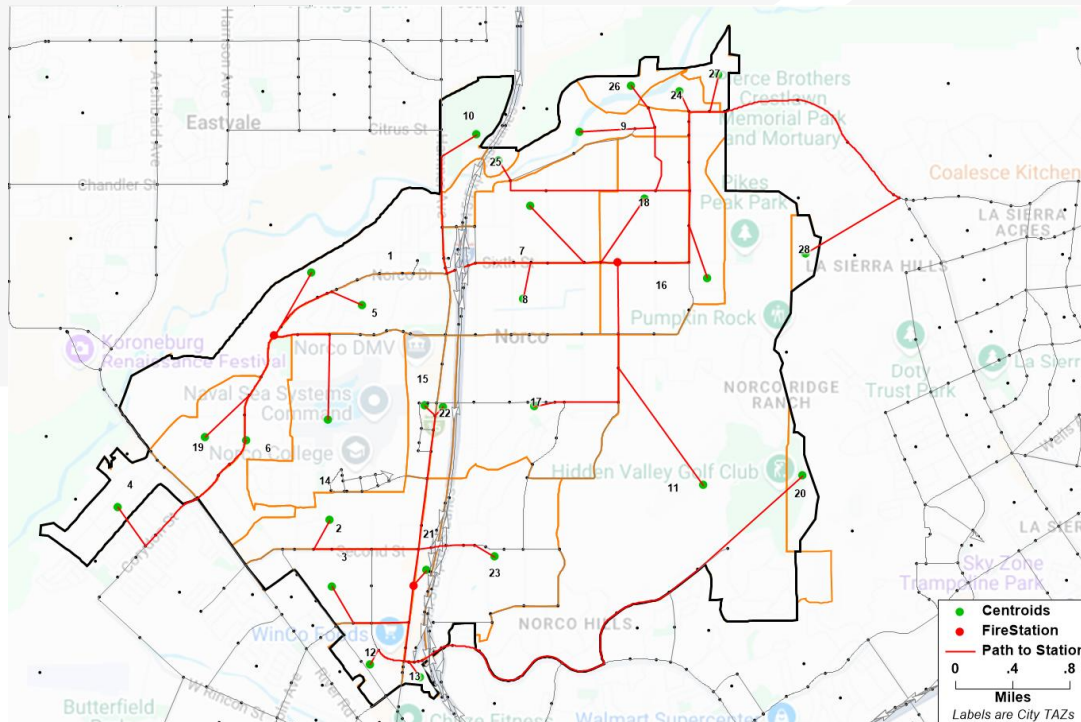- Additional measure of network connectivity and vulnerability.

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Distance to Shelters

Legend:
- Streets
- Emergency Shelters
- Centroids
- Paths to Exits

0   .5   1
Miles
Labels are City TAZs

➤ Identifies the shortest distance from every TAZ centroid to emergency shelters.

➤ Requires a network more detailed than a model network.

➤ Additional measure of network connectivity and vulnerability.

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Emergency Response Times

- Identifies the shortest peak travel time from every fire station to every TAZ.

- Additional measure of network connectivity and vulnerability.

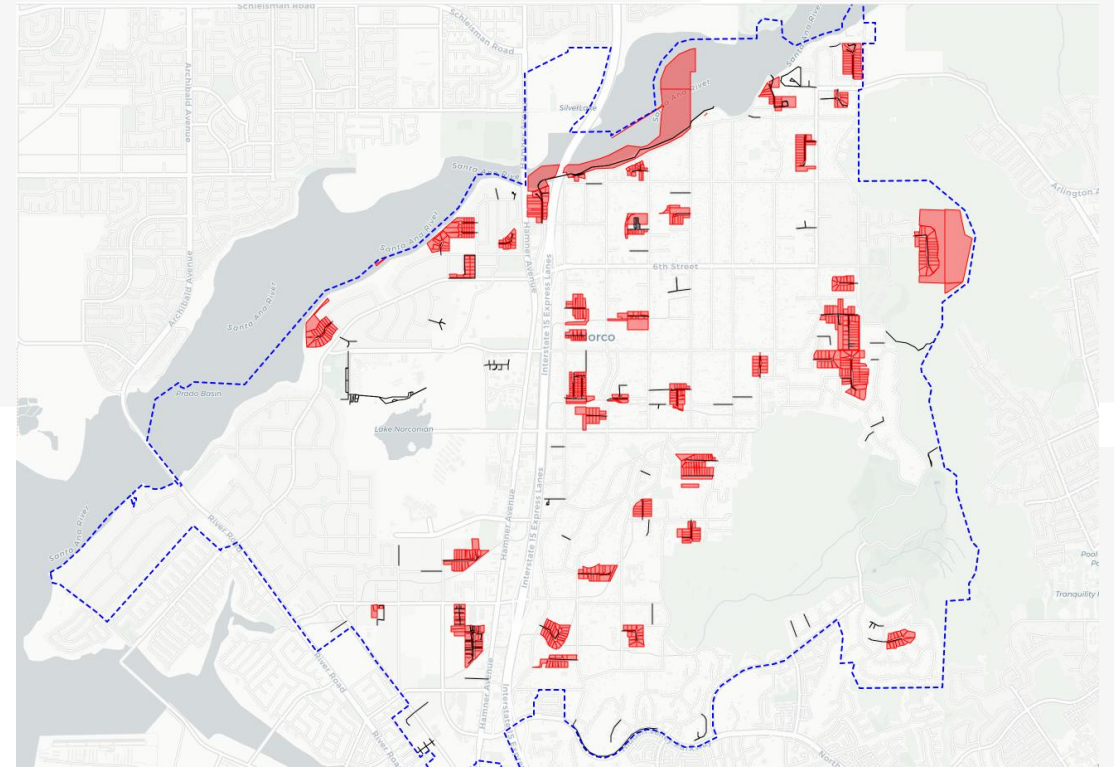- Uses congested travel times off the model network.

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AB 747: Average Evacuation Time

➤ Identifies vehicular demand by time of day.

➤ Identifies evacuation network capacity (vehicles/hour) depending on location of hazard.

➤ Calculates average evacuation time (minutes) as the ratio of demand to capacity.

Scenario	Evacuation Demand (vehicles)	Evacuation Capacity (vehicles/hour)	Evacuation Times (minutes)
AM Earthquake	31,541	34,130	55.45
AM Flooding	31,541	20,480	92.41
PM Flooding	47,206	20,480	138.30

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SB 99: Stranded Zone Analysis

→ Identifies combinations of parcels that have one ingress/egress which may be stranded in an emergency.

→ Uses the latest Open Street Map (OSM) network.

→ Identifies locations where network redundancies should be considered.

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Regional Evacuation Analyses

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Improvement Project Identification

Build upon SB-99 findings

Identify vulnerable facilities by overlaying network with hazard layer

Observe travel patterns during a historical evacuation event

Explore ITS infrastructure that can guide people during an evacuation

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Thank You for Your Time

Please reach out with additional questions or queries.

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