Wildfire Preparedness: Artificial Intelligence and Modeling in Wildfire Evacuation Planning

American Planning Association State Conference

September 30, 2024

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PANELISTS

Darin Neufeld, AICP
Harris & Associates,
Director

Andrew Scher, EIT
Fehr & Peers,
Transportation Engineer

Bowen Kyle
Ladris,
Chief Technology Officer

Harris & Associates

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WHAT IS A SAFETY ELEMENT?

The Safety Element is a required general plan element that assesses hazard risk and defines objectives and policies to:

Protect the health, safety, and welfare of the community

Address public safety hazards, including climate change

Build resilience, preparedness, and responsiveness to hazards

EMERGENCY EVACUATION ROUTE ANALYSIS REQUIREMENTS

AB 747

Requires local governments to identify evacuation routes and evaluate their capacity, safety, and viability under a range of emergency scenarios.

- Select Emergency Scenarios

SB 99

Requires local governments to identify residential developments in hazard areas that do not have at least two emergency evacuation routes.

- Define Evacuation Routes

AB 1409

Requires local governments to identify evacuation locations.

- Identify Evacuation Locations

OFFICE OF PLANNING AND RESEARCH: EVACUATION PLANNING TECHNICAL ADVISORY

General Plan Evacuation Requirements

General Plan Evacuation Planning Guidance

- Engage Early and Often
- Plan for a Range of Hazards
- Identify Residential Developments with Limited Evacuation Route Access
- Identify Applicable Emergency Scenarios
- Assess Evacuation Locations
- Assess the Capacity, Safety, and Viability of Evacuation Routes
- Identify Evacuation Routes and Locations

Example General Plan Policies and Programs

https://opr.ca.gov/docs/20220817-Fire_Hazard_Planning_TA.pdf

DYNAMIC TRAFFIC ASSIGNMENT:

EVACUATIONS AND EXTREME EVENTS

Presented by Andrew Scher

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AGENDA

Resiliency and Accessibility

Capacity Assessment

Evac +

Analyzing Results

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Types of Analysis

- **Resiliency Assessment:** How many access routes are available for an evacuation
- **Capacity Assessment:** How efficient is the transportation network during an evacuation

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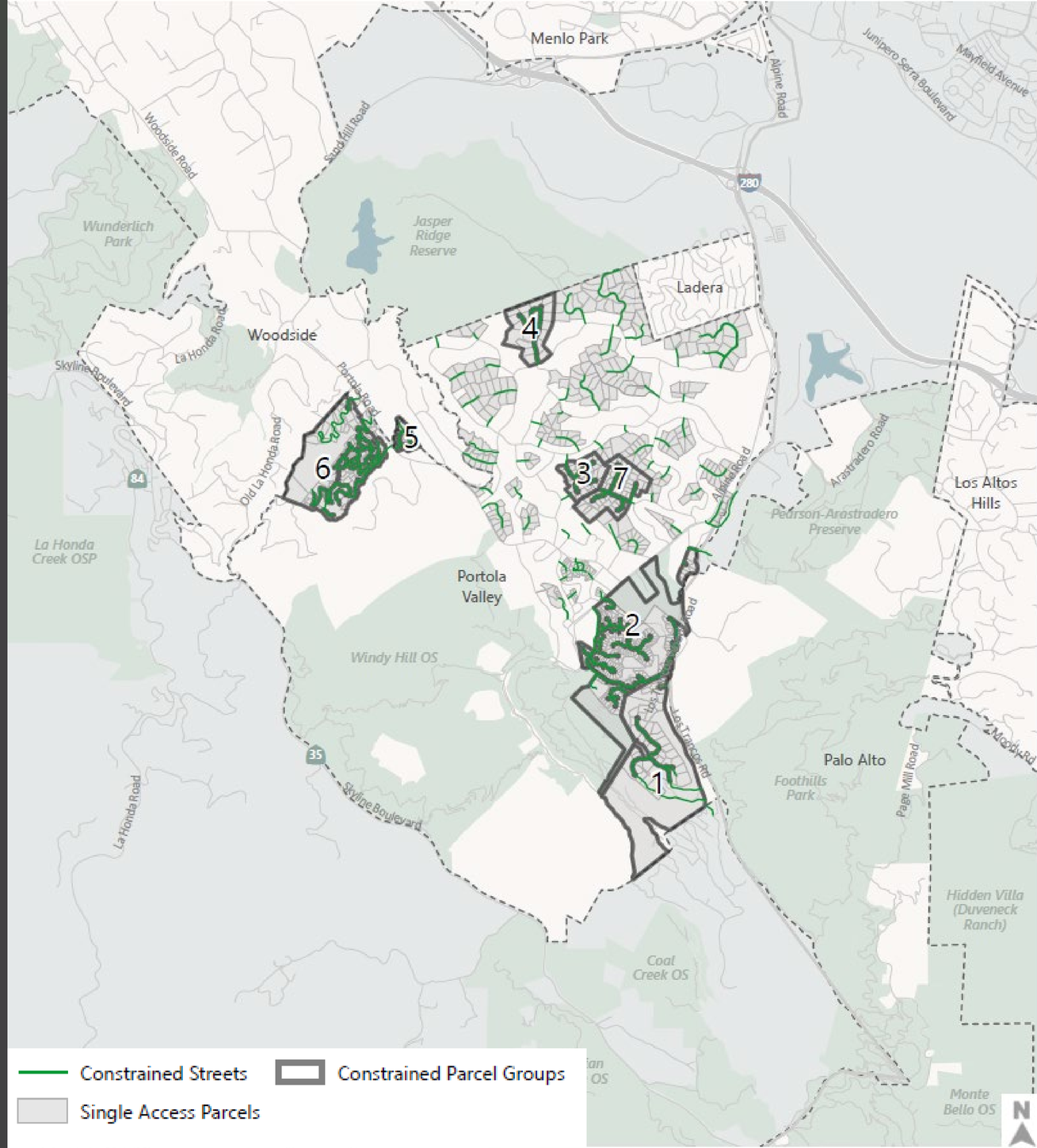
Resiliency

SB 99 Requires us to identify parcels and communities with only one point of access

Portola Valley Wildfire Traffic Evacuation Capacity Study *shows parcels and groups of parcels served by a single primary access route*



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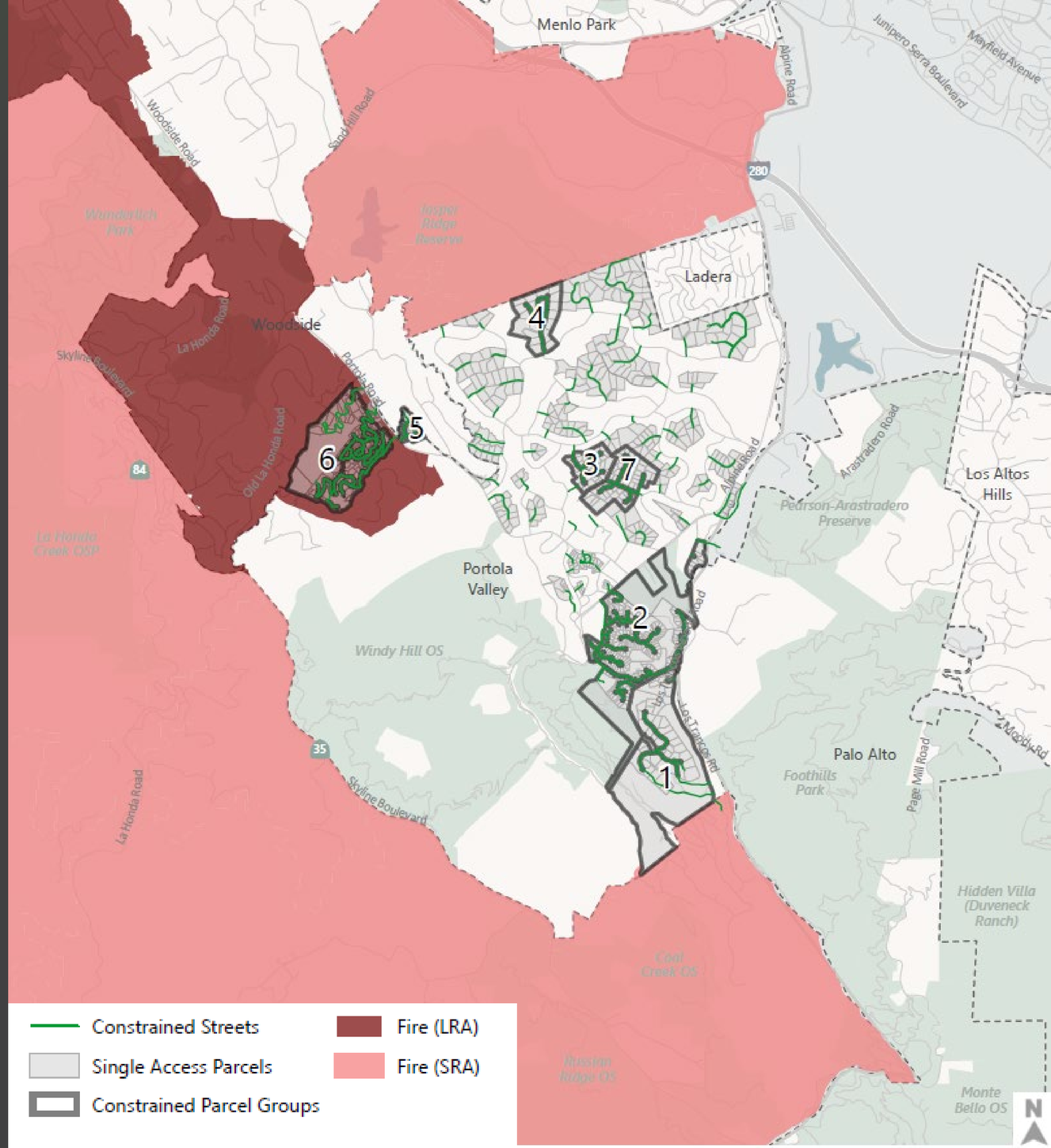
Resiliency

Portola Valley Wildfire Traffic Evacuation Capacity Study *shows how hazards overlap with constrained parcel groups and streets*

- Identify available routes for neighborhoods
- Distance neighborhoods must travel to get out of the City or get to shelters
- Identify neighborhoods which may lose access to evacuation routes during a major flood event



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Capacity Assessment

AB 747 Requires us to evaluate the capacity of the evacuation system

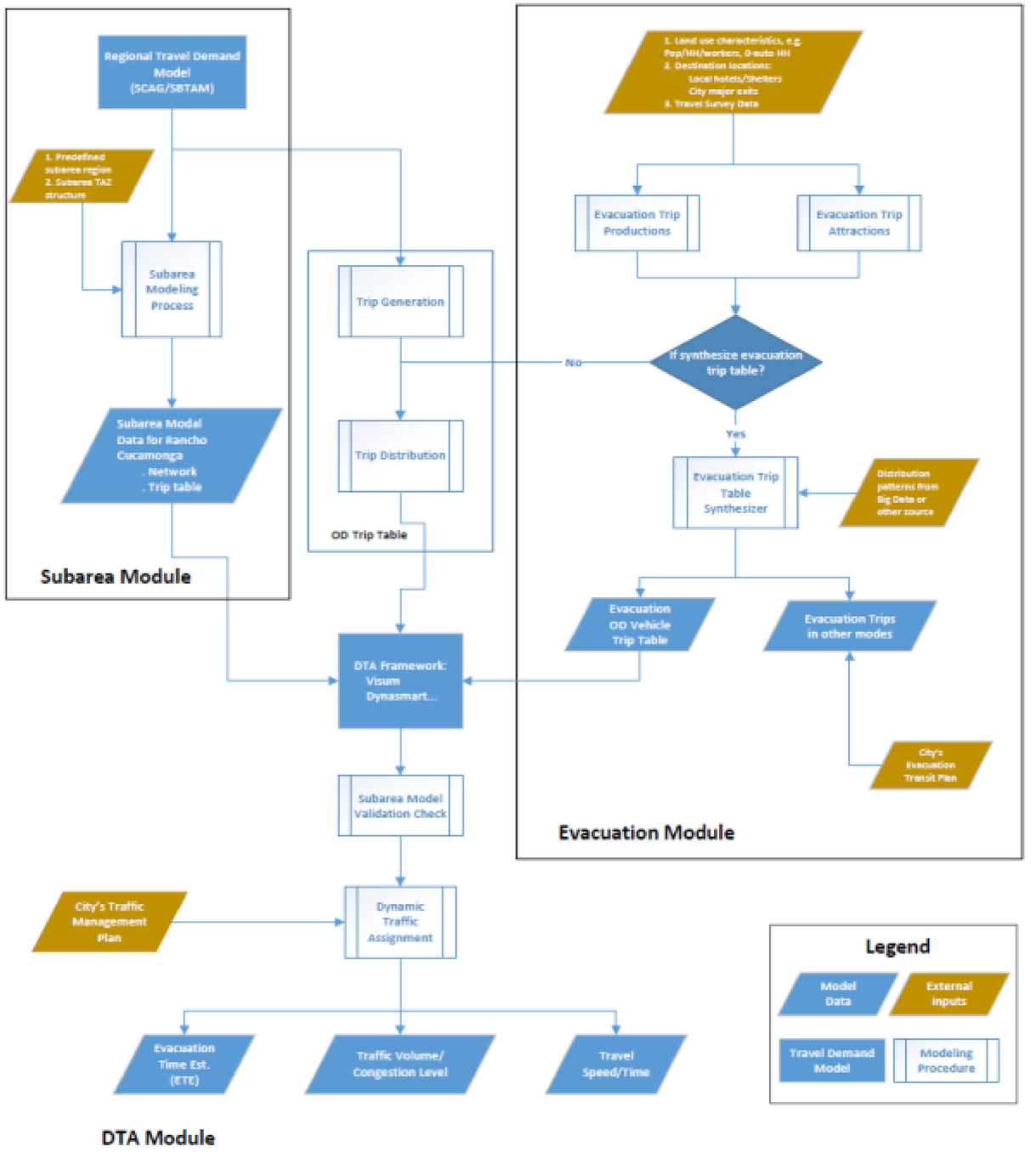

Exhibit E – EVAC+ Dynamic Traffic Assignment Module

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Methodology - Stages

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Photo Credit: kernvalleysun.com

Level of Effort

- **Lower effort:** Roadway capacity analysis compared to vehicles likely to evacuate
- **Medium effort:** Roadway capacity analysis plus Origin-Destination analysis to identify evacuation distances and multi-hazard interactions
- **Higher effort:** Modeled analysis of evacuation scenario(s) using Dynamic Traffic Assignment (DTA) evacuation module
    - If you anticipate a congested network with bottlenecks during the evacuation, particularly if they may affect route choice, use a simulation or Dynamic Traffic Assignment (DTA) Model to estimate ETEs

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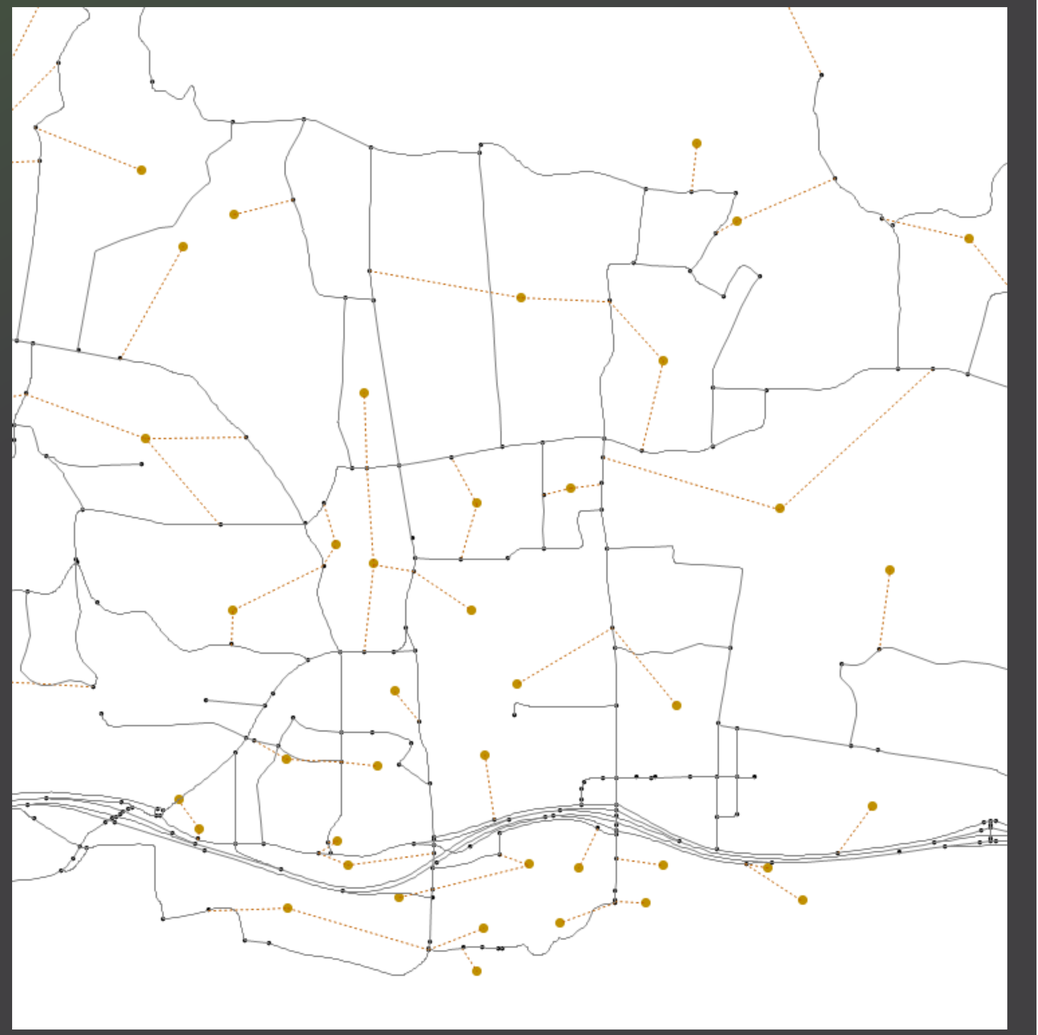
EVAC+ Subarea Model

- Start with travel demand model.
- Refine model network and land use data:
  - Isolate a geographic subarea from the model
  - Split Transportation Analysis Zones (TAZs)
  - Update socio-economic data
  - Refine and correct roadway network details, capacity assumptions, and speeds
  - Calibrate the model to reflect baseline conditions
  - Consider future roadway network modifications
  - Consider future land use growth



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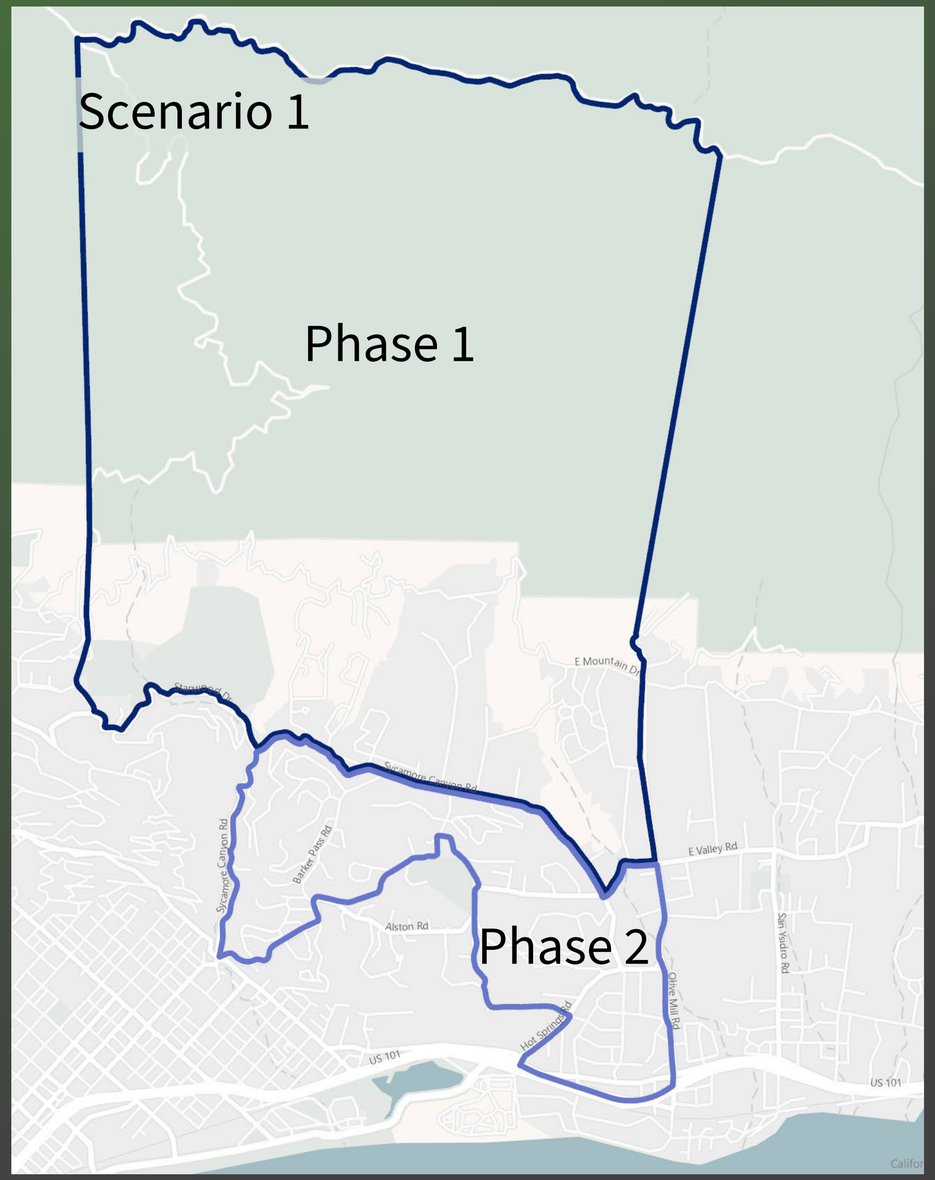
EVAC+ Process

1. Define evacuation scenario
2. Estimate trips during event (productions & attractions)
3. Distribute trips according to evacuation demand curve
4. Assign trips to roadway network to see how congestion accumulates
5. Evacuation time estimates

1. Define Evacuation Scenario



1. Define Evacuation Scenario

Network Considerations

- Modify network to reflect desired conditions
  - Road closures
  - Contraflow/additional evacuation capacity
- Modify network to account for reduced evacuation network capacity as relevant (e.g., effect of smoke and atypical driver behavior during wildfire/hazard event)
- Consider extracting total evacuation times when 90% and 100% of population are evacuated

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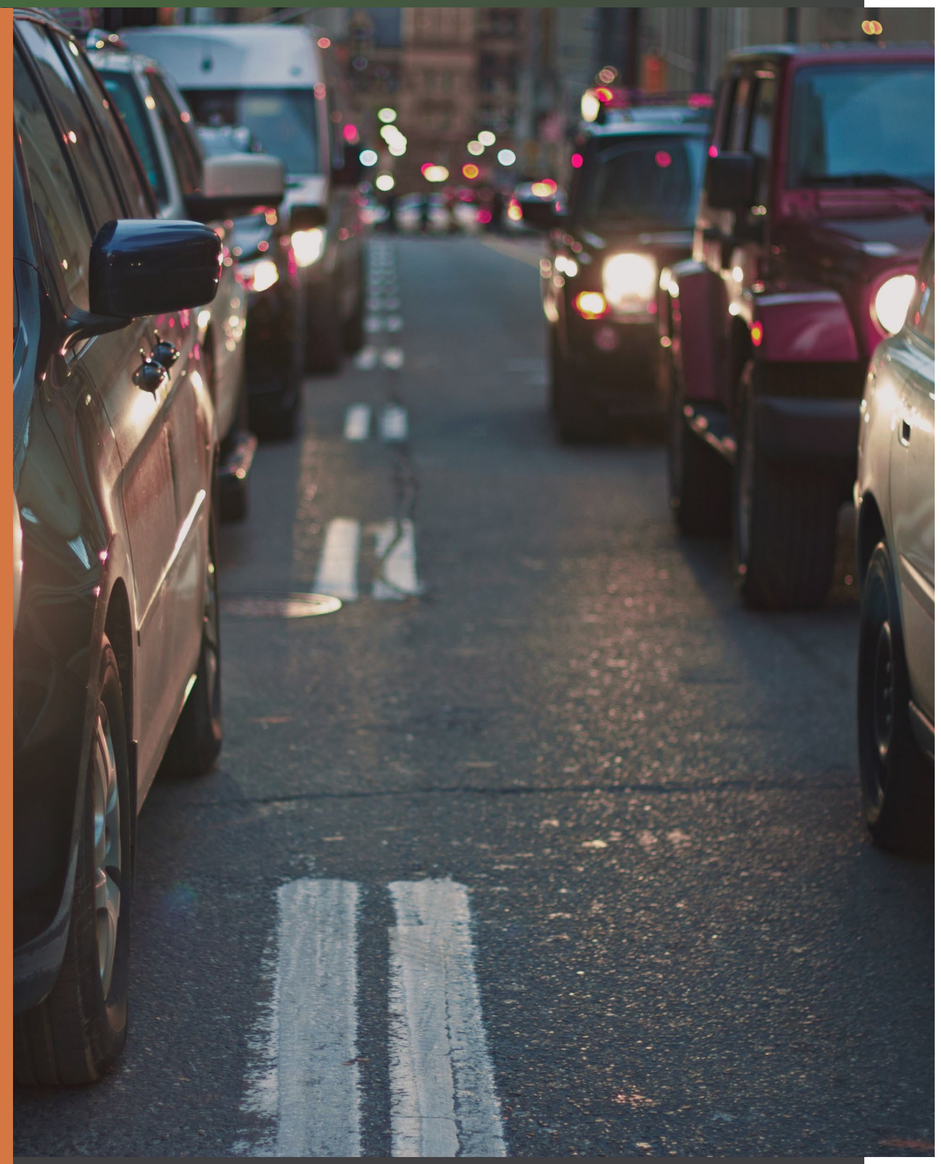

2. Estimate Trips

Vehicle Demand Considerations

- Forecast evacuation vehicle trips for **community population groups** and **project population groups** (residents, employees, and/or visitors)
- Estimate population of each group at time of evacuation notice(s)
- **Travel Demand Models:** Built to estimate weekday daily and peak hour demands for normal trip purposes
- **Residential Evacuation Trip Demand:** Varies based on household persons/vehicles/income levels (1.89 Veh/HH, UCB survey, 2017-19 fires)
- **Temporal Distribution** (i.e., Evacuation Trip Time Distribution Curves): Varies by population group, shortest for employees/visitors, longest for residents

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2. Estimate Trips

Parameters	Scenario 1	Scenario 2	Change
Scenario Description	• Phased evacuation of Zones 1, 2, 3, 8, 9, 10, 15, 16	• Phased evacuation of Zones 1, 2, 3, 8, 9, 10	
Time of Day	• 3:00-4:30pm	• 3:00-4:30pm	
Population	• 3,787	• 2,248	• -1,539
Households	• 1,123	• 517	• -606
Employees	• 569	• 522	• -47
College Students	• 745	• 745	• 0
Evacuation Trips	• 3,200	• 2,085	• -1,115

Trip Distribution	• 92% of trips sent E/W beyond the model area
	  • Of these, 40% east, 60% west
	  • 95% on US-101; 4% on SR-192; 1% by other arterials
	• 8% internal to the model area
	  • All of these sent towards Santa Barbara, mostly to beach-front hotels		

3. Distribution of Trips

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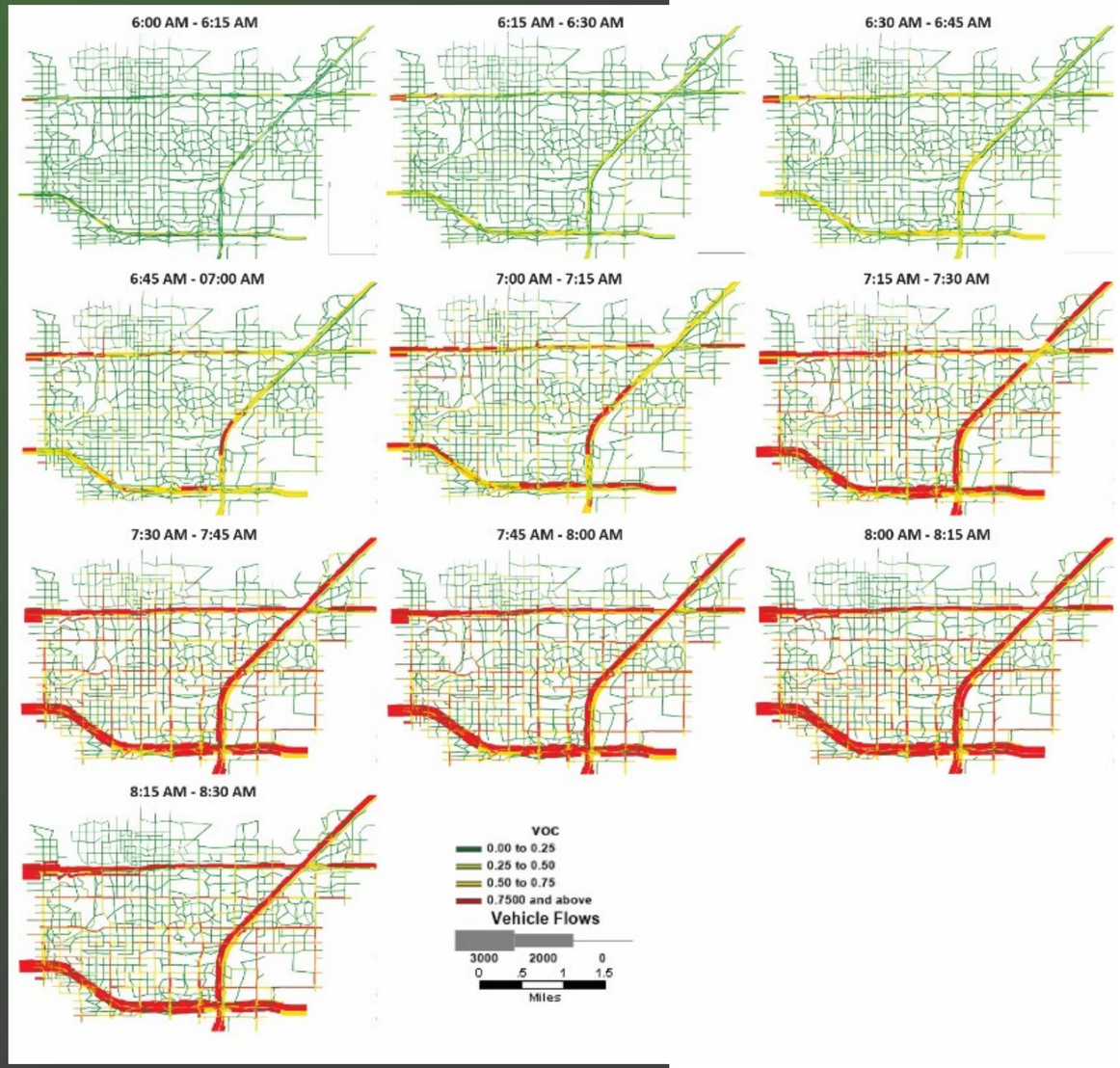
Evacuation Time Distribution Assumptions

Time Interval	Phase 1	Phase 2
3:00-3:14	100%	2%
3:15-3:29	0%	8%
3:30-3:44	0%	21%
3:45-3:59	0%	31%
4:00-4:14	0%	18%
4:15-4:30	0%	20%

Share of Trips Ending in Different Evacuation Destinations

Description	Share of Trips	Details
Hotels	8%	Based on a review of hotel capacity in the subarea
Shelters/Stadiums	0%	No shelters or stadiums in the subarea
East	36.8%	95% on US-101 Southbound 4% on SR-192 1% on other E/W arterials
West	55.2%	95% on US-101 Northbound 4% on SR-192 1% on other E/W arterials
North	0%	No trips evacuating North
South	0%	No trips evacuating South



4. Assign Trips

Dynamic Traffic Assignment (DTA) Evacuation Module

- Accounts for background traffic on any through routes from Subarea Model
- Considers Evacuation Trip Productions and Attractions
- Considers evacuation-specific distribution patterns (informed by big data or other data sources)
- Inputs Evacuation OD Vehicle Trip Table into DTA Framework
- Considers integration of Evacuation Transit Plan
- Dynamic assignment in 15-minute increments

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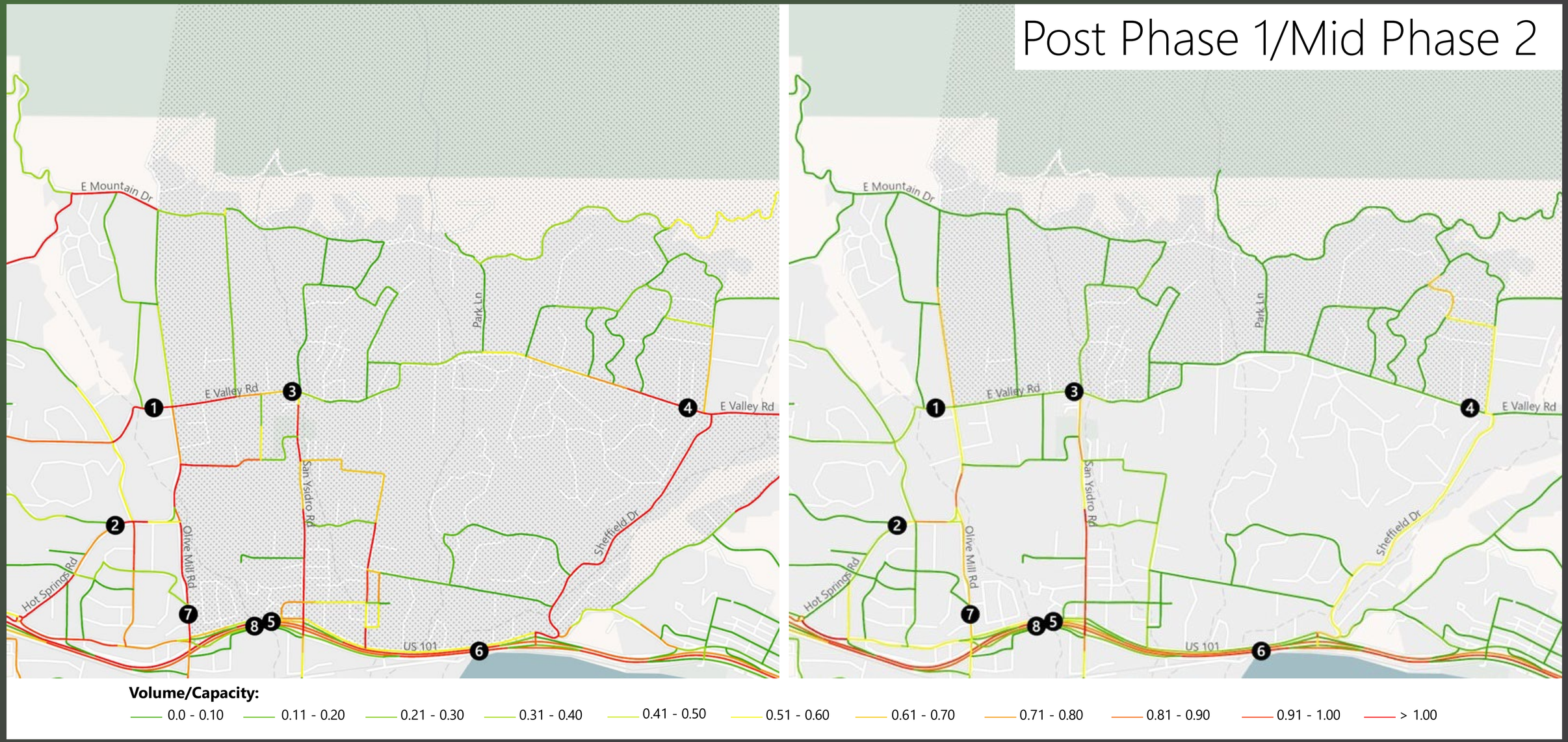
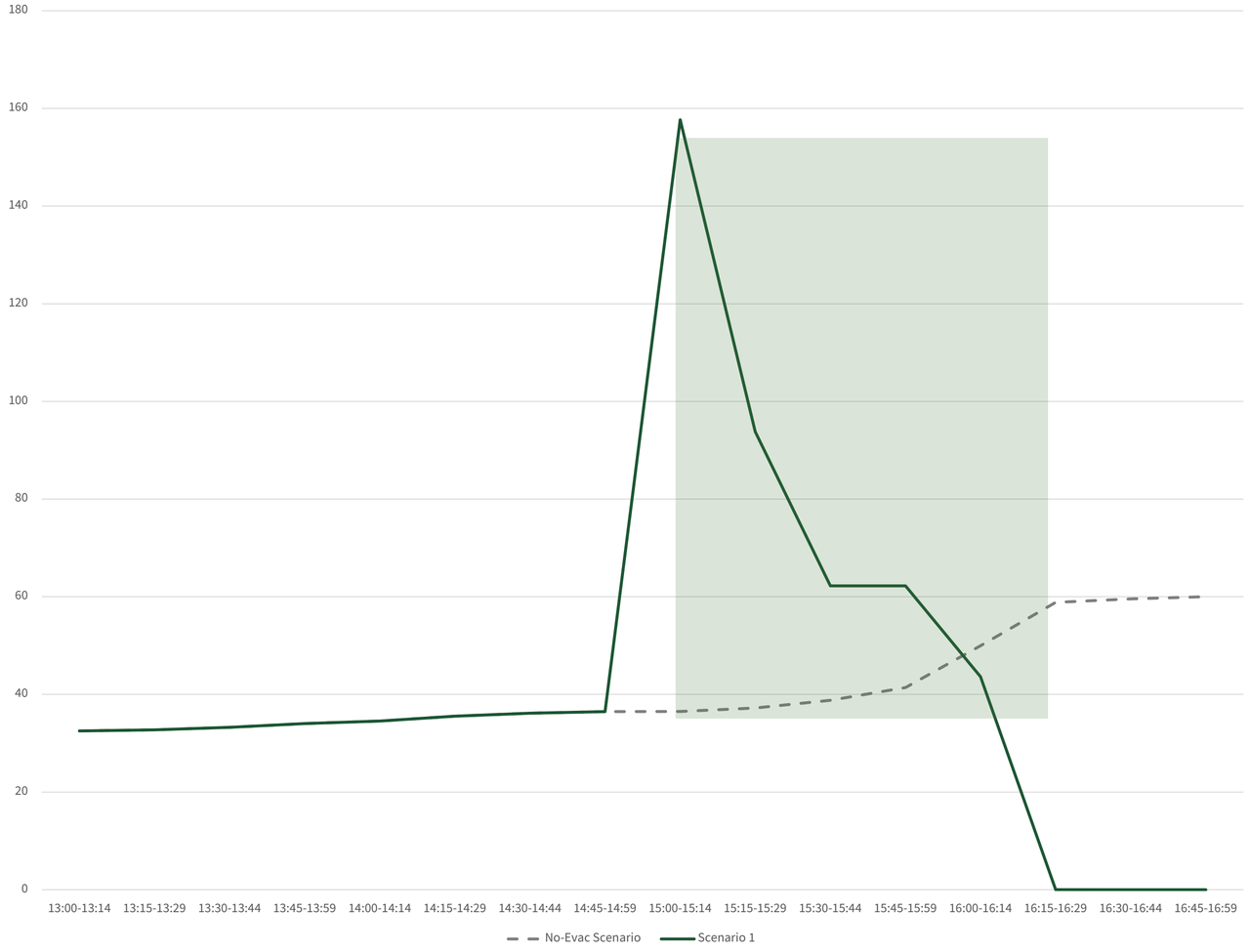
4. Assignment: Congestion per 15-minutes

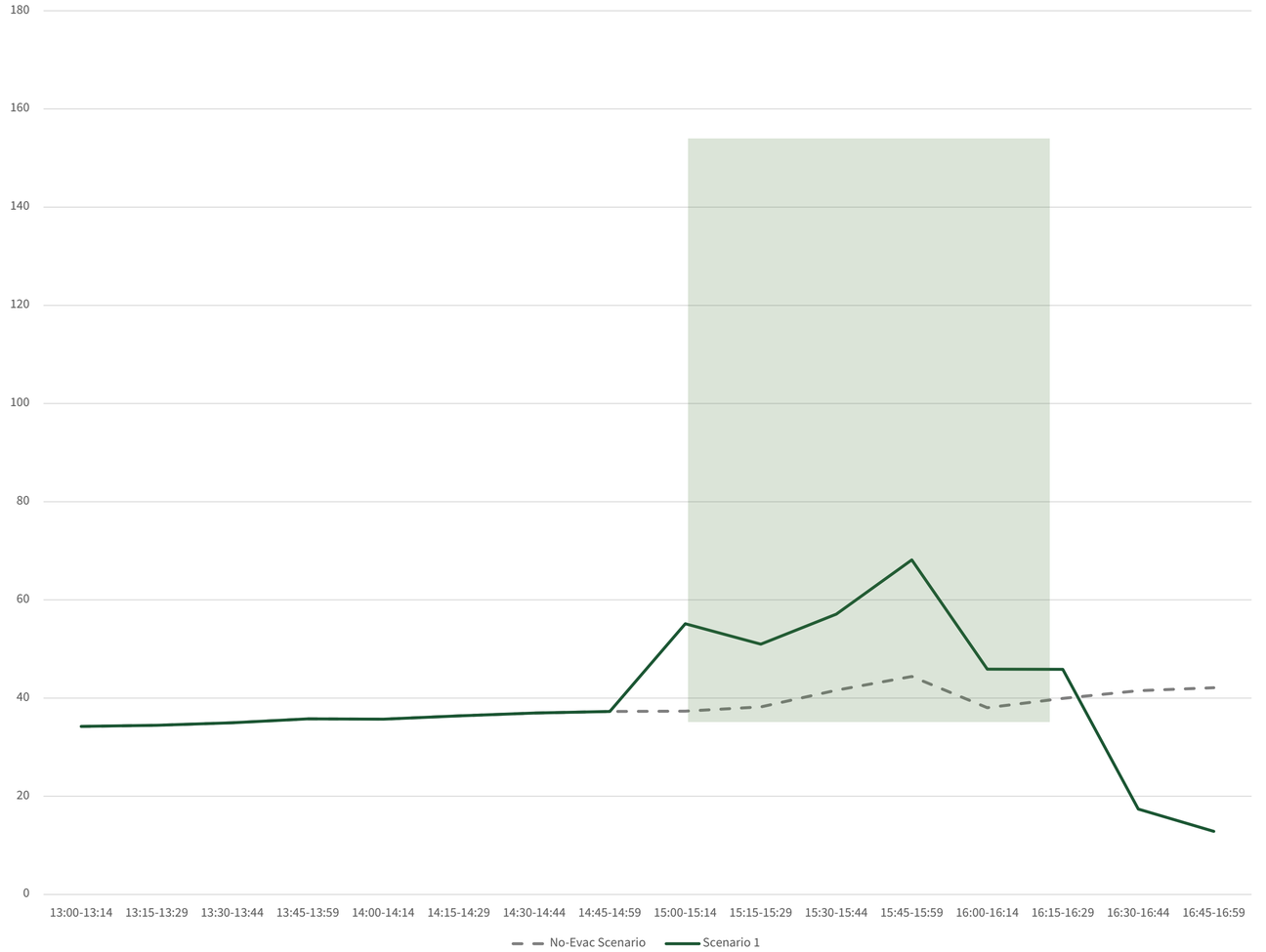


4. Assignment of Trips

Scenario 1

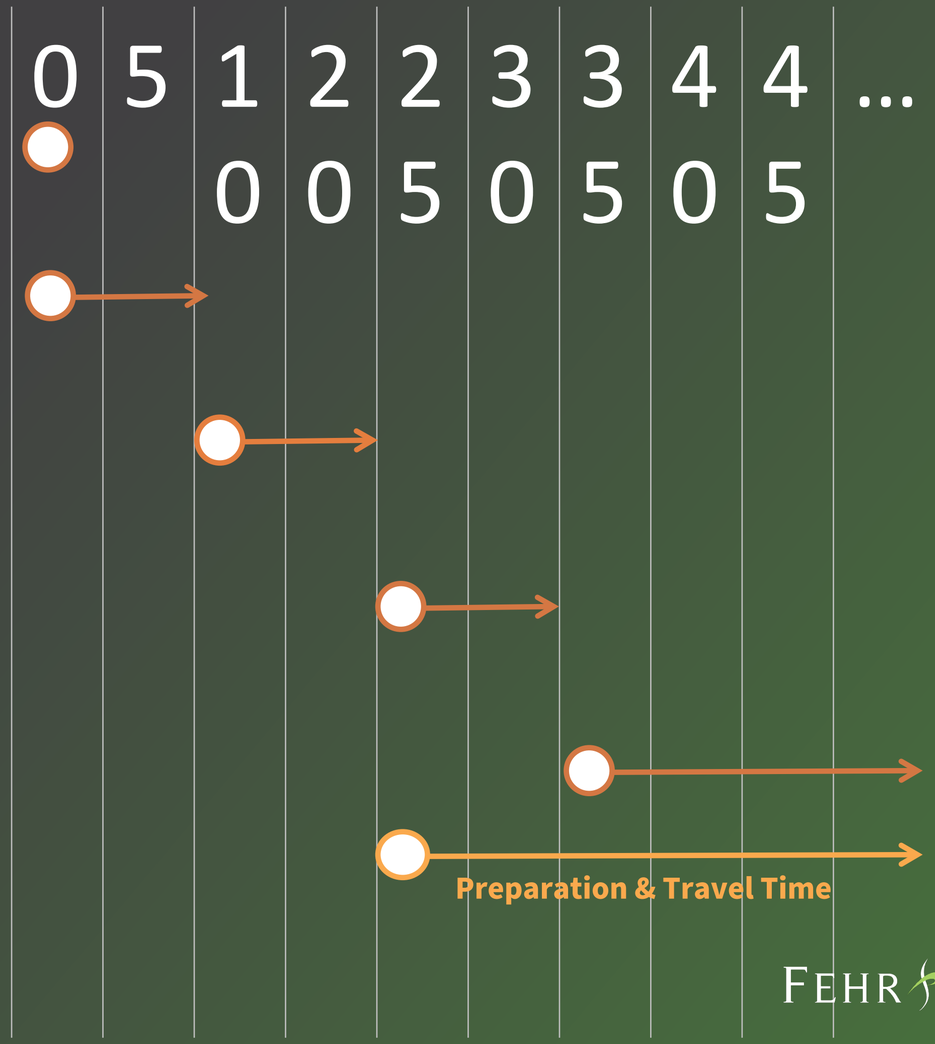


Scenario 2



5. Evacuation Time Estimates (ETEs)

"Clock" starts when a hazard is first identified



Hazard Detection
Time when hazard is first identified

Hazard Notification to the Public
Time when any official releases an evacuation order

Evacuation Order Received
Time when people receive the evacuation order

Preparation
Time to prepare to depart after receiving evacuation order

Travel
Elapsed time from evacuation order until last vehicle clears evacuation area includes time moving and delay due to congestion

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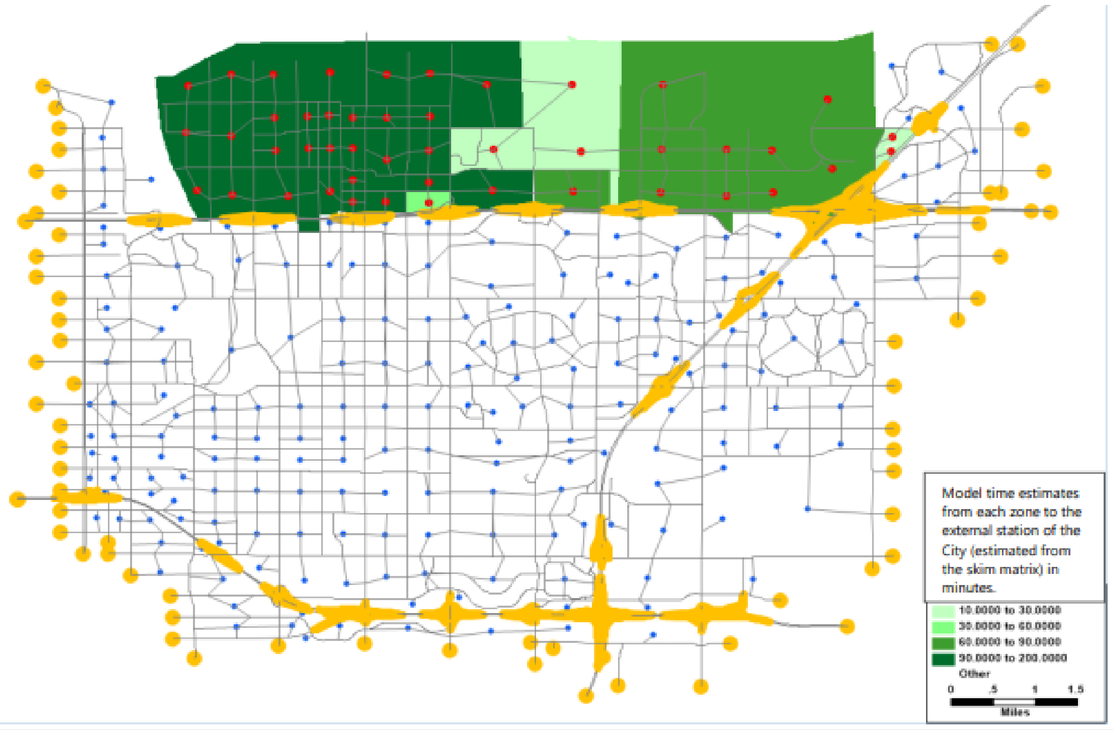
5. Evacuation Time Estimates

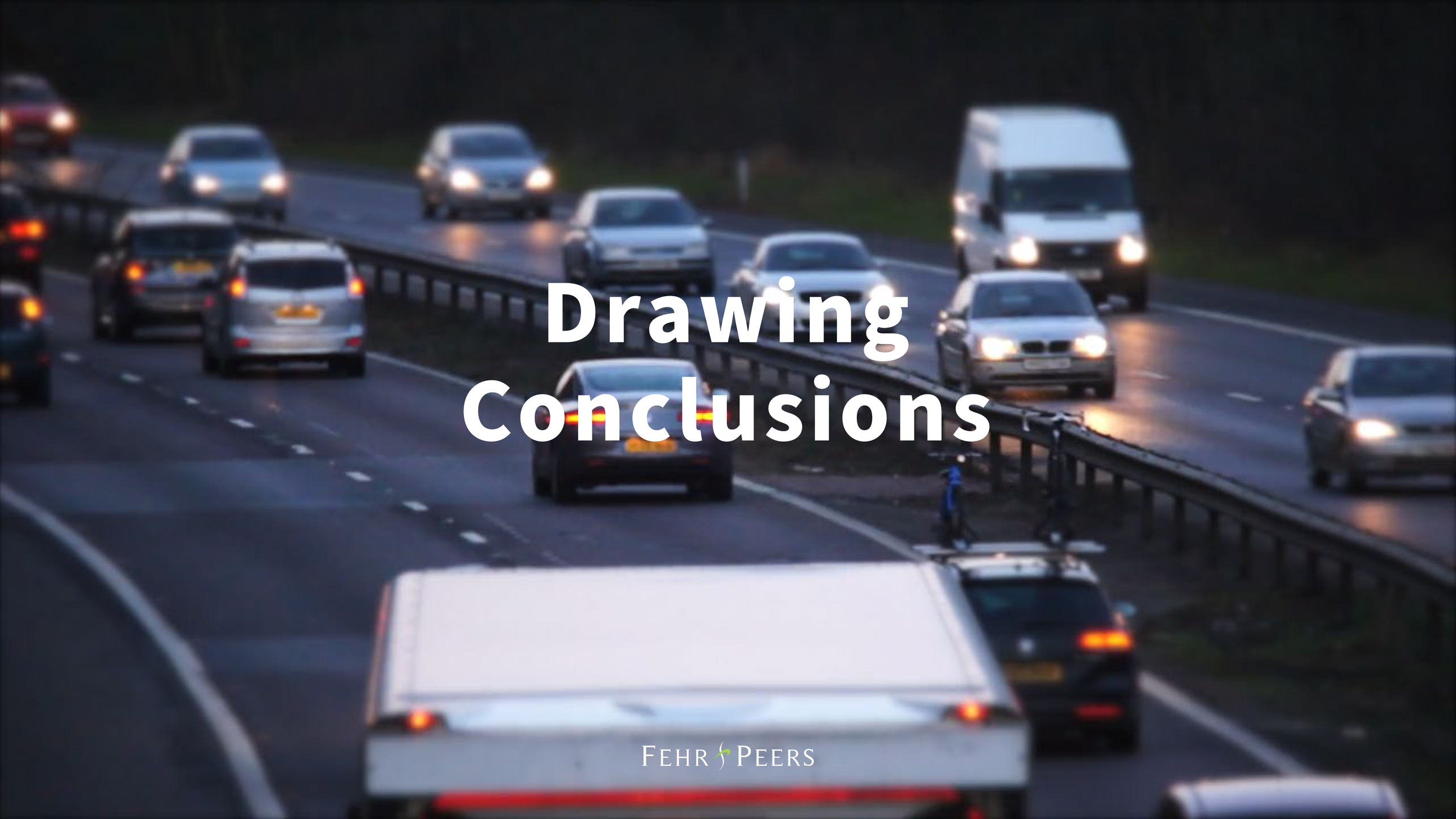
Table 4: Roadway System Capacity Assessment

	Scenario 1	Scenario 2	Scenario 3 and 5	Scenario 4
Total Vehicle Trips	8,667	17,940	26,596	99,126
Exit Link Hourly Capacity*	10,695	11,098	17,038	43,078
Link Time for Evacuation Assuming All Trips are Evenly Loaded on the System**	49 minutes	97 minutes	94 minutes	138 minutes
Time To Exit Evacuation Area***	75 minutes	105 minutes	150 minutes	255 minutes

Note: No work or school return trips included, as those trips have not yet been made when the evacuation occurs.
*: only includes the capacity of the direction out of the evacuation area.
**: the time that the exit links require to handle all the evacuation trips assuming those trips are evenly loaded at the same time, used as reference.
***: assumes a bell curve distribution for traffic loading from receipt of the evacuation order.

Figure 12: Time to Evacuate Areas North of SR-210





Drawing Conclusions

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Testing and Determining Strategies to Reduce ETEs

- **Demand-Side:** Timely departures, phased evacuation, triggered evacuations, vehicle reduction, hardened shelters
- **Supply-Side:** Shoulder usage, ramp closures, route closures, turn restrictions, signal priorities, manual traffic control, public transit, mode shift, parking restrictions
- **Information-Side:** Early Hazard detection systems, rapid information delivery, evacuation preparation, route preparation, dynamic route guidance, system monitoring, travel information

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Toolbox of Evacuation Strategies

Planning

- Multi-Jurisdiction Evacuation Routes Map
- Focused Evacuation Plans for High Congestion Areas
- Contraflow Operations Plan
- Freeway Ramp Closure Plan (Caltrans)
- Multi-Agency Evacuation Coordination Plans
- Resilience Hub/Facility Hardening
- Evacuation Plans for Schools And Senior Care Facilities
- Phased Evacuation Feasibility Assessment
- Evacuation Scenario Assessments

Programs

- Community Evacuation Education
- Evacuation Route Roadside Fuel Break Program
- Narrow Street Parking Management Plan (High Hazard Days)
- Early Notification System for Parcel Clusters with Single Egress Route
- Evacuation Intersection Traffic Management
- Vehicle Crash Emergency Clearance Crews
- Transit Agency Evacuation Support
- Evacuation Vehicle Demand Reduction Program

Projects

- Intersection Traffic Control Improvements
- Directional Road Lane Widening
- Dual Purpose Shoulder Evacuation/Protected Bike Lane Widening (Egress Only)
- Fire Road Enhancements for Emergency Vehicle Access
- Second Egress Routes for Constrained Parcel Groups
- Evacuation Wayfinding, Signs, And Barriers
- Dynamic Route Guidance and Monitoring System
- Hazard/Wildfire Early Detection Systems (Cameras, Drones)
- Communication System Hardening

Additional Planning Considerations

Equity

Who is affected when areas of the jurisdiction lose access in an emergency?

- Race/ethnicity
- Income
- Age
- Gender
- Employment sector

Vulnerability

Who might have a harder time evacuating?

- Vehicle ownership
- Household size
- Disability status
- Pets/animals
- Linguistic isolation
- Hospitals, schools, prisons, group homes, tourists

Policy Response

How does the jurisdiction intend to use the information revealed through the evacuation analysis?

- Inter-agency coordination
- Land use decisions
- Transportation operations plans, infrastructure, state of good repair

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THANK YOU

a.scher@fehrandpeers.com

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Wildfire Preparedness: Artificial Intelligence and Modeling in Wildfire Evacuation Planning

Bowen Kyle, Ladris CTO

Leveraging AI Technology for
Safe, Accurate and Efficient Evacuations

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Evacuations: No Longer a Rarity

Evacuations of **1,000** or more people occur approximately every **two to three weeks** in the US

Sandia National Laboratories

75% of these events involve small-scale evacuations of fewer than **5,000** individuals

Sandia National Laboratories

Disasters displaced more than **3 million** Americans in 2022

Census Bureau

Evacuations can happen **anywhere**, **anytime**

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Introduction to AI in Evacuation Planning

- What is AI?
  - Artificial Intelligence (AI) is a field of study and technology development focused on building machines and systems capable of performing tasks that typically require human intelligence. These tasks include learning from data, recognizing patterns, making decisions, and understanding natural language.

    Source: National Artificial Intelligence Initiative Office (NAIIO)

- How can AI be Applied to Evacuation Planning
  - AI is a force multiplier enabling the ability to think about multiple scenarios in emergency situations and use predictive modeling.
  - AI is not meant to be a substitute for the expertise of emergency managers.

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AI-Based Software

01 Real-Time

02 Unlimited Number of Simulations

03 Multiple Data Sources

04 Proprietary AI Software

05 Unrestricted Execution; Use Remotely

06 Force Multiplier

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An AI Evacuation Tool Provides Answers to Two Fundamental Problems

1. Who Needs To Be Evacuated?

1. Where Should They Be Evacuated To?

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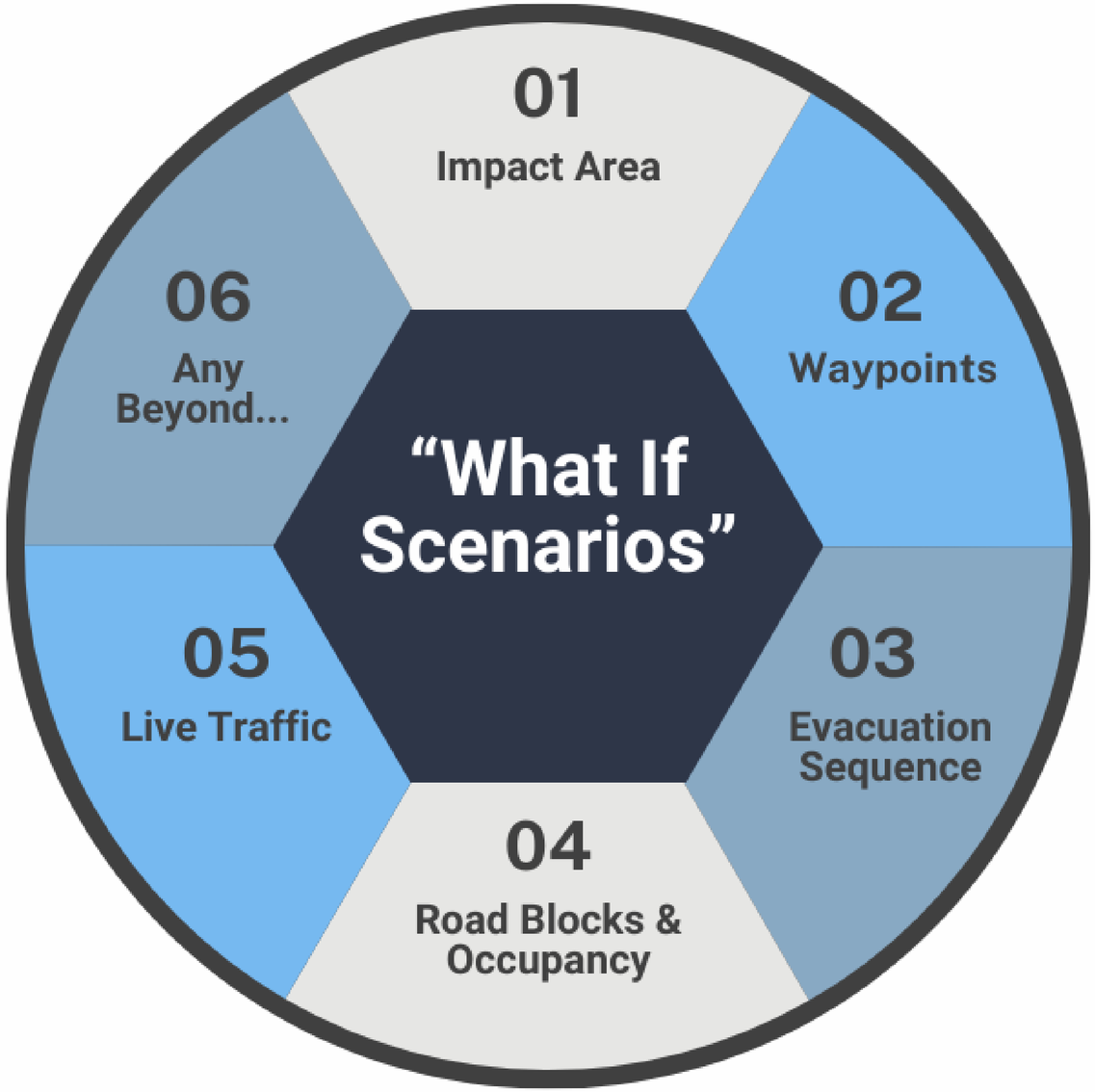
Attributes of an AI-Enabled Evacuation Tool

- Easy to Use
- Intuitive Dashboard
- Intelligent Insights
- Powerful Visualizations
- Detailed Analysis
- Run 1, 100 or 1000 Scenarios
- Simulation Feedback in Seconds
- Supports Public Engagement
- Accurate

AI Results Using Six Inputs



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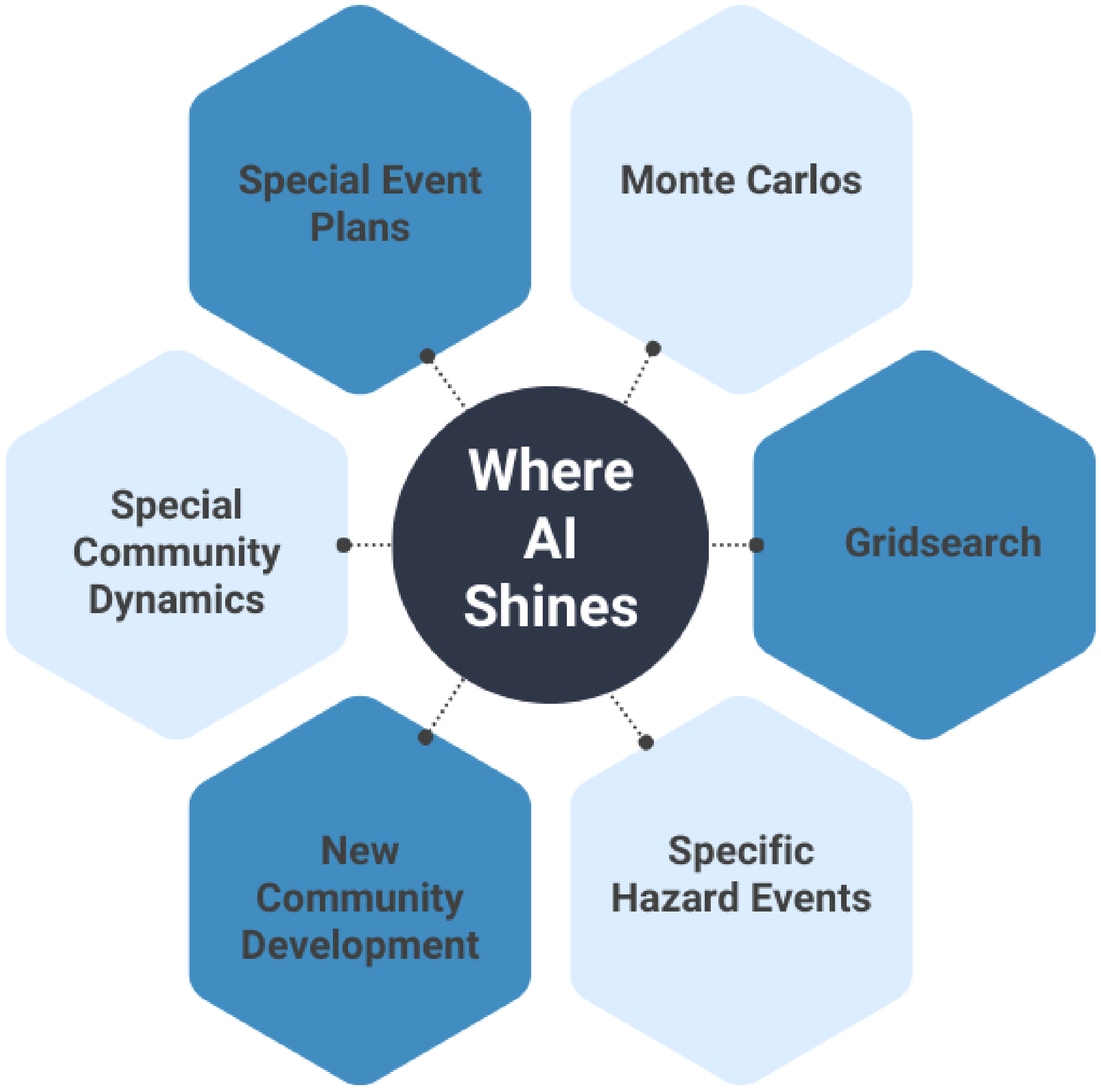
Special Event Plans
Monte Carlos
Special Community Dynamics
Where AI Shines
Gridsearch
New Community Development
Specific Hazard Events

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AI-Driven Key Metrics

Quantitative

- Number of Addresses Evacuated
- Number of Passenger Cars
- Number of Heavy Vehicles
- Single Vehicle Worst-Case Evacuation Time
- Average Vehicle Time
- Standard Deviation

Visual

- Representation of How Evacuation Could Work - Individuals Leaving Addresses
- Witness the Congestion on the Roads Forming and Dissolving

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AI-Enabled Predictive Modeling Demo

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Thank You!

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