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TECHNICAL MEMORANDUM

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Project# 25492

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Project TCTC Evacuation Routes and Communication Strategies

RE: Task 3: Strategies for Increasing Capacity and Efficiency

INTRODUCTION

This memorandum describes a set of strategies identified for improving the capacity and resilience of the County roadway network to support potential future evacuation events. The strategies were identified based on previous congestion and evacuation studies, review of recent evacuation efforts, and staff feedback. The strategies are organized into six groups:

1. Roadway Capacity and Resilience
2. Intersection Capacity and Resilience
3. Added Routes for Evacuation Planning
4. Improve Development and Vulnerable Community Access
5. Evacuation Management Guidance
6. Additional Demand Management

For each individual strategy, the following is identified:

- **Description** – Describes the strategy and desired outcomes. For example, while some strategies will increase capacity to meet projected needs, other strategies may seek to more efficiently conduct evacuations within available roadway capacity. It also identifies if the strategy is primarily an engineering or design project, an operational strategy, or a communication strategy.
- **Implementation Needs** – Identifies steps for planning for and implementing the strategy.
- **Limitations** – Notes considerations and potential drawbacks that could limit effectiveness or proclude use of the strategy in specific locations.
- **Case Studies** – Where there are applicable examples, case studies, or research, identifies where the strategy has been implemented and high-level notes.

At the end of the memorandum is a list of additional research and references that support or provide additional examples for the strategies. Following the modeling of the evacuation network, the strategies will provide a basis for developing concepts for potential evacuation

resiliency improvements at priority locations identified as having limited capacity during one of the evacuation scenarios.

The strategies presented in this memorandum are new and evolving and were chosen based on relevance to Tuolumne County. Appropriate case studies were chosen where possible; in some cases, no applicable examples could be identified.

GROUP 1 – ROADWAY CAPACITY AND RESILIENCE

This group includes strategies and treatments to improve vehicle flow and capacity along roadways. For each of these treatments, it is necessary to consider downstream capacity limitations and identify if those limits nullify potential benefits of the treatment.

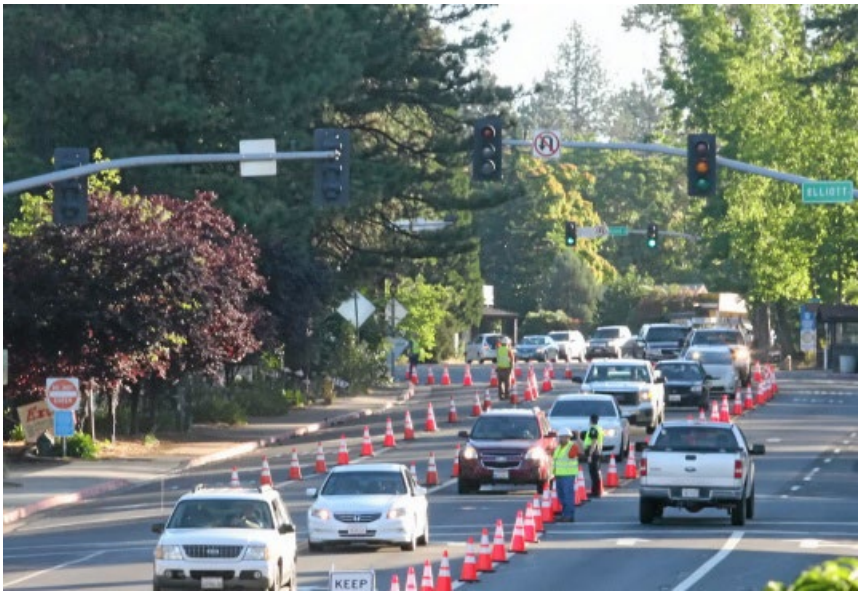
1.1 REVERSIBLE LANE/CONTRAFLOW

Description: Operational strategy where capacity is added in one direction by reorienting one or more travel lanes to flow in the direction of the evacuation and away from the hazard. This strategy can be attractive since it generally requires minimal infrastructure changes. Reversible lanes can be set up over long distances, such as highways, or on localized segments, such as in neighborhoods that may only have a single egress route.

The strategy requires staff to implement traffic control at intersections to prioritize evacuation movements and restrict turn movements and lane changing (e.g., on- and off-ramps along highways). In particular, intersections must be set up to prevent traffic in the closed direction. Signage and other safety measures need to be implemented on both sides of the roadway to ensure drivers are aware of roadway changes, especially along longer stretches where contraflow is implemented.

Managing movements at intersections is critical. As a result, staffing and level of effort to establish the treatment depends on the number of intersections along the roadway, with the treatment being harder to implement on roads with more intersections.

Figure 1: Reversible Lane Test – Paradise, CA



Source: Paradise Post, Rick Silva

Implementation Needs:

Prior to Implementation:

- Staffing plan, including an implementation leader, a communication leader, and number of staff to be deployed to evacuation areas.
- Plans for reorienting traffic, including (1) ensuring available routes for emergency vehicles to travel against traffic, and (2) altering intersection operations to avoid conflict at sites where roadways connect with the evacuation route with reversible lanes.
- Timeline for implementing the strategy, including time needed to clear traffic from the lane that will be reversed and time to reroute traffic from connecting roadways.
- *Potential Construction Needs* – Implementation may require roadway or shoulder expansion to provide sufficient space for emergency vehicles to travel against traffic. Reversible LED lane signs can also be considered to visually communicate the change in direction of traffic during an evacuation.

During Implementation:

- Staff to be deployed to intersections to manage vehicle flow and prevent vehicles from entering the reversible lanes from connecting roadways.
- A communication plan for staff during implementation.
- Signs, cones, and/or bollards for road closures and detour routes.

Limitations: One of the primary limitations of the strategy is whether the roadway cross-section and right of way provide sufficient space to allow emergency vehicles to travel against evacuation traffic (either in a travel lane or on the shoulder). Contraflow also requires a large

number of staff, enough resources (e.g., cones and signs), and sufficient time to implement. Staffing limitations may delay the implementation of the strategy or limit where the strategy can be implemented.

Case Study:

- Pacific Coast Highway Contraflow during the 2018 Woolsey Fire[1]

1.2 EMERGENCY SHOULDER USAGE

Description: Engineering and operational strategy that is a variation on Reversible Lane/Contraflow. Under the strategy, the shoulder of a roadway is widened and paved to allow for use as an additional lane of traffic for personal or emergency vehicles during evacuation. Cones or other markers may be used during implementation to identify lanes or reallocate space, as necessary, especially around intersections where the shoulder could conflict with normal turn patterns.

Where possible, the strategy may be preferred over reversible lanes/contraflow because it can be implemented very quickly, does not close the roadways to vehicles that would travel in the opposite direction, and requires less operational support for securing travel lanes and readjusting intersections.

See Strategy 3.2 for a related option. Under the strategy, a shared use path could be constructed along a roadway which could function as an emergency path during an evacuation.

Implementation Needs:

Prior to Implementation:

- Implementation plan, including signage, cones or other barriers, and timeline for implementation.
- Staffing plan, including an implementation leader, a communication leader, and number of staff to be deployed to evacuation areas.
- *Potential Construction Needs* – Review existing shoulders and available shoulder width for candidate sites. Design and construct wider, paved shoulders where possible. Shoulders along evacuation routes could be marked with evacuation signs in advance to reduce the number of staff needed to place signage during an evacuation event.

During Implementation:

- Staffing to set up signage and cones/flex posts/bollards for shoulders.
- A communication plan for coordinating staff during implementation.

Limitations: In Tuolumne County, most shoulders are not sufficiently wide to currently support the strategy. As a result, this strategy would likely require road widening and removal of trees or

[1] https://la.curbed.com/2018/12/13/18131163/wildfire-earthquake-evacuations-cars

other existing infrastructure, resulting in high construction costs. Consideration should be given to the presence of trailers, campers, and other wide loads which may complicate required travel widths. Staffing limitations may delay the implementation of the strategy.

Case Study:

- Florida DOT (FDOT) Emergency Shoulder Use[2] - Florida uses the strategy to increase traffic capacity during hurricane evacuations on highways. FDOT is replacing contraflow and lane reversal plans with emergency shoulder use since they do not require blocking traffic and securing and moving traffic across crossover sections of the interstate.
  - Note that this strategy may not be directly applicable to Tuolumne County due to the scale of the strategy and different evacuation scenarios (i.e., evacuations due to hurricanes and flooding). This strategy may be scaled down to certain areas in the County or along shorter segments of the roadway where shoulders are already wide enough for vehicles

GROUP 2 – INTERSECTION CAPACITY AND RESILIENCE

This group includes strategies and treatments to limit bottlenecks at intersections and reduce the potential for conflict. For each of these treatments, it is important to determine downstream intersection capacity limitations (i.e., are benefits dependent on intersection treatments?).

2.1 SIGNAL COORDINATION – GREEN CARPET (UNINTERRUPTED FLOW)

Description: Operational strategy where traffic signals along a corridor are set to prioritize the through the movement of evacuation traffic by (1) holding or reducing movement from side streets and (2) restricting left-turn movements. To minimize evacuation time, vehicles leaving the impacted area are prioritized while movements from areas not-yet impacted are restricted. This strategy can also discourage evacuees from detouring from the evacuation route. The strategy can also be applied in small areas where there may be a single traffic signal.

Implementation Needs:

Prior to Implementation:

- Identify corridors or locations where traffic signals are present and treatment is appropriate (e.g., holding movement from side streets does not prevent people from evacuating).
- Create implementation and staffing plan to facilitate evacuation, including training staff to manually change signals if necessary.
- Develop local circulation plans (e.g., Tuolumne County Community Maps[3]) for communities where traffic might be held from major road. For example, develop plans to allow continued movement of people in Sonora if evacuation is prioritizing locations east of the city.

[2] https://www.fdot.gov/emergencymanagement/esu/default.shtm
[3] https://www.tuolumnecounty.ca.gov/1169/Community-Maps

- Establish requirements for integrating new traffic signals into the system. If signals require manual changes, develop plan for implementing changes.

During Implementation:

- Track evacuation needs to ensure priority is given to areas most in need of evacuation (e.g., roadways with exisiting capacity issues).
- Staff at intersections where side-street traffic will be held to explain the situation and discourage illegal movements or to set up detour signage.
- A communication plan for staff to coordinate strategy implementation along the green carpet corridor.

Limitations:

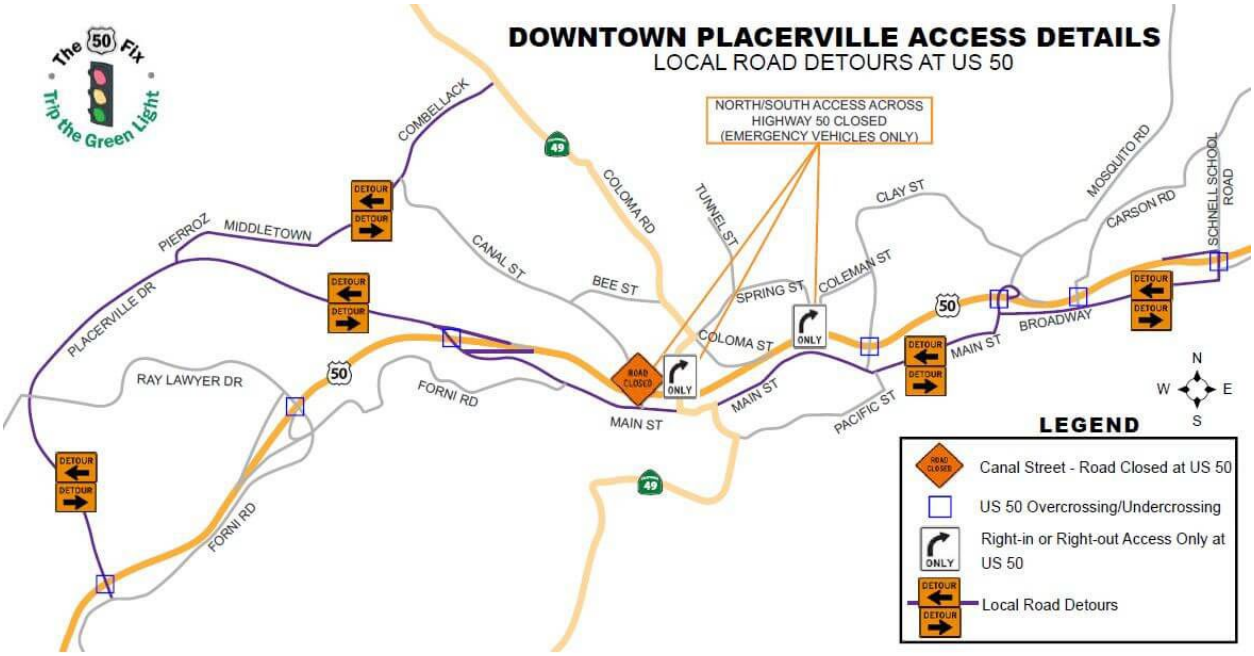
- Strategy is likely not appropriate if evacuation is necessary from the communities impacted by the side-street red light. Tuolumne County has some communities with only one egress route, such that limiting use of the mainline road unacceptably limits local movement.
- May create additional confusion for drivers, either because it (1) prevents evacuees from diverging from through movement or (2) restricts drivers from entering from minor streets.
- Relatively few traffic signals in Tuolumne County for the strategy to be implemented at. The strategy does not provide Countywide benefits.
- Staff limitations may reduce the number of locations the strategy can be implemented at, especially if traffic control is needed.

Case Study:

- City of Placerville and Caltrans implemented a green carpet through the city of Placerville during evacuation for the Caldor Fire.[4] The green carpet was used to support evacuation of people residing east of Placerville. Caltrans District 3 deployed operators to implement signal changes and Placerville city staff put up signage for temporary closures supporting the green carpet and shared maps for local detours. Figure 2 shows the detour maps that the city of Placerville distributed for local detours.

[4] https://www.sacog.org/news/caldor-fire-evacuees-greeted-green-lights-through-placerville

Figure 2 Downtown Placerville Example



Source: El Dorado County

2.2 SIGNAL COORDINATION – DYNAMIC FLASHING YELLOW

Description: Operational strategy that is an alternative to the green carpet strategy. Under the strategy, traffic signals are set to use a flashing yellow signal on the main evacuation approach and a flashing red on the side street. This strategy may be more appropriate than a green carpet at intersections where a) side streets have significant traffic demand and/or b) there is an absence of available detour routes to serve side street traffic.

In Phase 1, flashing yellow–flashing red (FY/FR), the traffic signals on the main street flash yellow, whereas the side street signals flash red. In Phase 2, green–red (G/R), the main street signal will stay red, and the side street signal will turn green. The goal of using the G/R phase is to quickly clear waiting vehicles on the side streets. Figure 3 shows a signal plan for a dynamic flashing yellow.

Figure 3 Dynamic Flashing Yellow Timing Plan

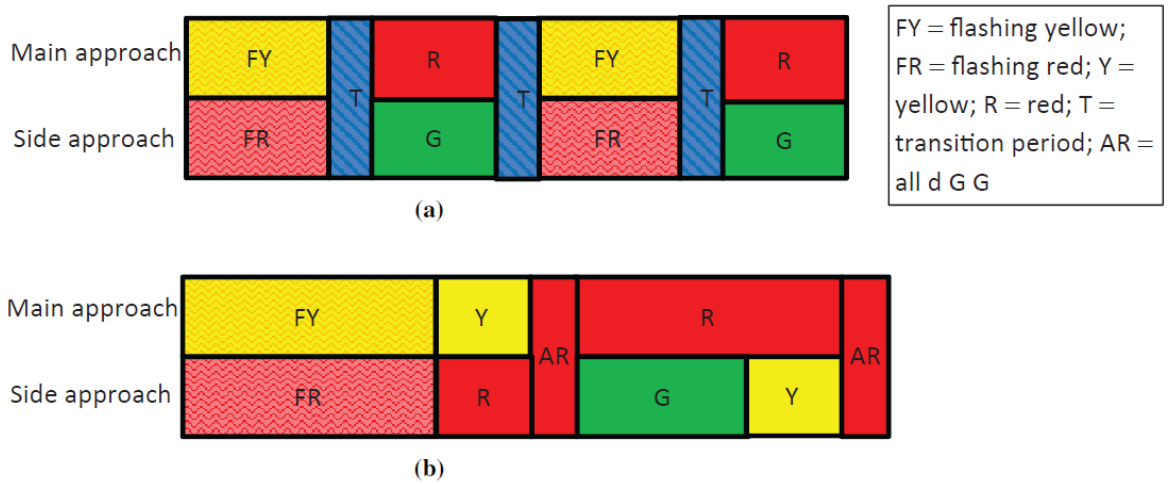


FIGURE 1 DFY signal timing plan: (*a*) two phases and (*b*) phasing in one cycle.

Source: Asamoah, C. A. (2014). Dynamic flashing yellow for emergency evacuation signal timing plan in a corridor: Semantic scholar. undefined. Retrieved May 4, 2022, from https://www.semanticscholar.org/paper/Dynamic-flashing-yellow-for-emergency-evacuation-in-Asamoah/f896455e97acf37f0cd01cc5f3bbb1ddbb79fc29

Implementation Needs:

Prior to Implementation:

- Identify corridors or locations where traffic signals are present and treatment is appropriate.
- Create an implementation plan for the strategy to facilitate evacuation, including staffing and communication plans.
- Establish requirements for integrating new traffic signals into the system.

During Implementation:

- Track evacuation needs to ensure priority is given to areas most in need of evacuation (e.g., roadways where capacity issues are already present, areas with no available detour routes for evacuations).
- Staffing potentially needed for managing side-street queues if there is concern of significant back-up under the alternative timing.

Limitations:

- Relatively few traffic signals in Tuolumne County.
- Staff may be needed to assist with managing traffic. In particular, drivers at extended red lights may elect to ignore signals. Staff limitations may reduce the number of signals where strategy can be implemented.

2.3 PREPARE FOR SIGNAL OPERATION DURING POWER OUTAGE

Description: Traffic signals may lose power prior to or during an evacuation due to a disruption caused by a fire or utilities shutting off power to avoid causing fires. New battery technology can substantially increase the time signals can operate on back-up power. If a traffic signal is not working, it can result in reduced throughput and increased crash risk.

In addition, during a power-outage, signals may default to an all-way stop. This prioritizes safe operation of the signal, but results are lower overall throughput. In the case of an evacuation, lower throughput could substantially reduce the efficiency of an evacuation. As a result, staff could evaluate whether to use an alternative timing during an outage, such as the flashing-yellow timing plan, or deploy staff to manage intersections instead of the default outage signal plan.

Implementation Needs:

Prior to Implementation:

- Review default signal timing behavior during power outages.
- Identify locations for setting specific evacuation timing in the case of a power outage.
- Identify how long a power outage may occur to understand need for battery backup.
- Identify where staff may need to be deployed for traffic control in the case of signal failure.

Implementation:

- Update batteries based on technology best able to meet evacuation needs.
- Identify signals where power outages may exceed existing battery power.
- Plan for power-outages during a evacuation, by either setting default signal operations or by planning for deployment of staff to manage intersections.

Limitations:

- In the scenario where staff are needed at intersections for traffic control, staff limitations may delay strategy implementation or reduce the number of intersections where the strategy can be implemented.

Case Study:

- San Diego County began updating their traffic signals to replace existing lead, acid-based backup battery to nickel-zinc batteries. The change is projected to increase how long signals can run on back-up energy from four to six hour to more than 24 hours.[5]

[5] https://timesofsandiego.com/politics/2021/10/08/county-begins-to-place-long-life-batteries-in-traffic-signals-as-prep-for-outages-emergencies/

GROUP 3 – ADDED ROUTES FOR EVACUATION PLANNING

Group 3 includes strategies and treatments to increase the number of potential routes available for evacuation. These strategies will be further evaluated in subsequent work where trail data, forest service roads, and fire routes are evaluated for appropriateness.

3.1 MAINTAIN ROAD AND SHOULDER CLEARANCE PROGRAM FOR SECONDARY ROADS

Description: Creates a more resilient evacuation system by annually clearing critical secondary roads to reduce fire risk during evacuation. Based on context, specific roads may be identified for engineering treatments such as shoulder widening or tree removal to support use for evacuation. Plans may consider maintaining smaller or more difficult to travel roads exclusively for use by emergency vehicles.

Implementation Needs:

Prior to Implementation:

- Identify non-State roadways that provide primary or secondary evacuation routes.
- Identify roadways for clearing programs or additional treatments (e.g., shoulder widening).

During Implementation:

- Conduct clearing program for secondary roads

Limitations:

- Clearing roadways can be expensive and requires targeting of resources.

Case Study:

- The District of Makenzie, British Columbia was awarded grant funding to reduce flammable fuel along Highway 39, the only major egress route for evacuations. Fuel reduction treatments were applied on 120 hectares of high-risk areas along the corridor and fuel management prescriptions are planned for another 70 hectares.[6]

3.2 CONSTRUCT SHARED USE PATH THAT SUPPORTS VEHICLES

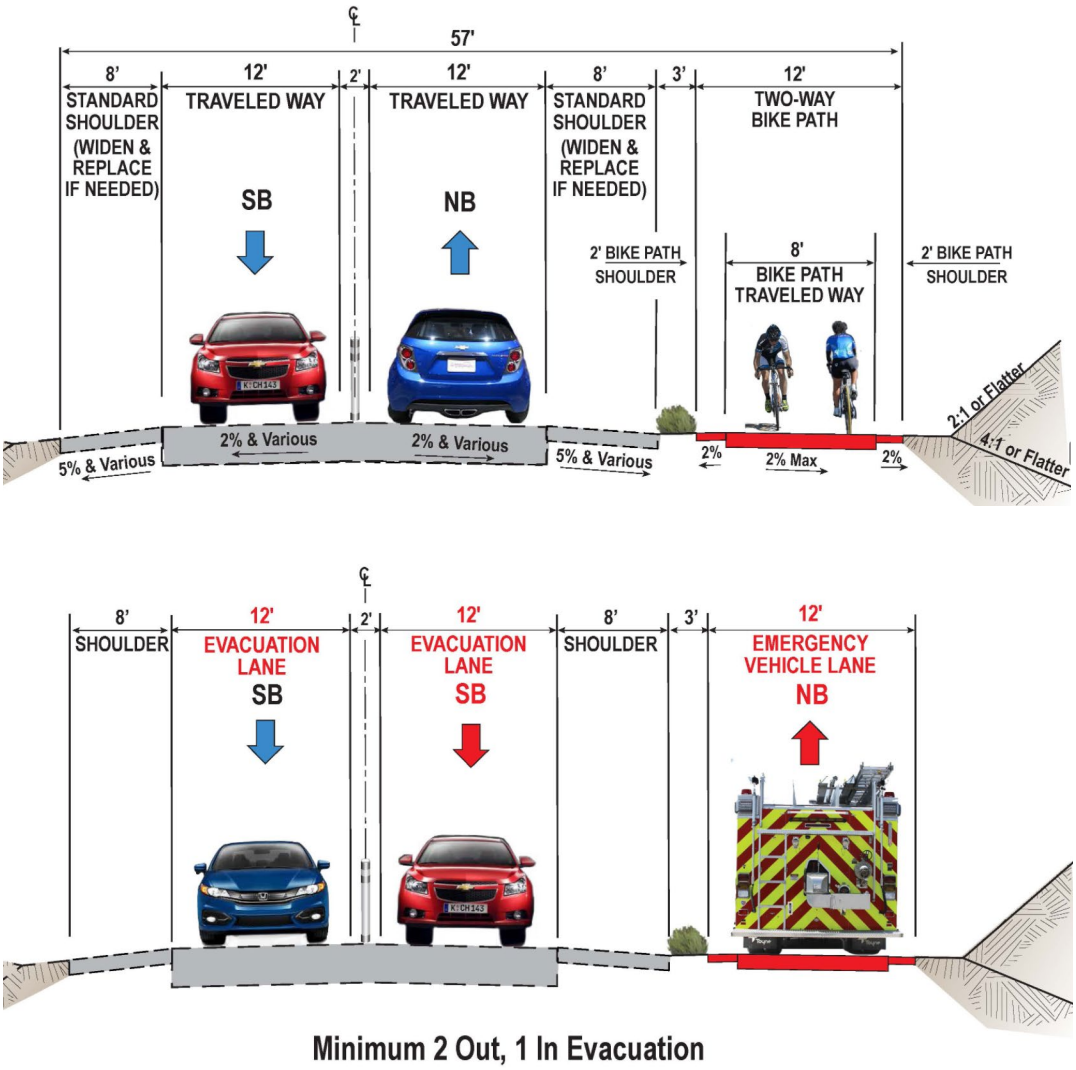
Description: An engineering strategy that constructs a shared use path that is built to a standard that would allow use by residential or emergency vehicles during an evacuation. Outside of an emergency, the shared use path would be accessible to residents and visitors for walking and biking. This strategy could be implemented separate from or parallel to a primary evacuation route. If constructed parallel to a primary evacuation route, the strategy would have similar operational benefits to Strategy 1.2 Emergency Shoulder Use.

This strategy requires careful access management design that prevents access to personal vehicles during normal periods, but which can be altered to allow emergency vehicle access

[6] https://www.fesbc.ca/community-of-mackenzie-now-has-a-safe-emergency-evacuation-route/

when necessary. Figure 4 presents an example of s shared use path that can be converted to an evacuation route or emergency vehicle lane.

Figure 4: State Route 67 Alternative with Two-Way Bike Path / Emergency Vehicle Lane



Source: Caltrans, https://dot.ca.gov/caltrans-near-me/district-11/current-projects/sr67-corridor/improvements

Implementation Needs:

Prior to Implementation:

- Identify zoning and land uses where shared use paths can be constructed.
- Review characteristics of the land to identify if the route would be appropriate for construction, including:
  - Provides a substantial benefit for emergency vehicles or evacuees.

- Grade change is either appropriate for vehicles or could be accomplished through reasonable efforts (e.g., can be constructed on a short timeline, through available funding, etc.).
- Maintenance is manageable (e.g., appropriate staff and funding is available).

During Implementation:

- Construct shared use path, including gates, bollards or flex posts that can be removed for vehicle access during evacuations.

Limitations:

- Cost-intensive strategy and potential for substantial land acquisition costs.
- Land adjacent to roadways may be owned by an assortment of agencies, including the City of Sonora, Tuolumne County, Chicken Ranch Rancheria of Me-Wuk Tribe, Tuolumne Band of Me-Wuk Tribe, USFS, and private owners. Coordination with landowners may be required if shared use paths are constructed through land not owned by the County.

Case Study:

- Caltrans is considering an alternative as part fo the State Route 67 Improvement Project in Southern California that would construct a two-way bike-path parallel to the road that could be redeployed for emergency vehicles.[7]

3.3 CONVERT PATH OR FIRE-ROAD TO POTENTIAL VEHICLE ACCESS ROUTE

Description: Identify locations where a new evacuation route or service road for emergency vehicles could be developed by modifying or converting a bike lane, path, or fire-road to serve potential evacuation routes. Depending on characteristics of the route, the bike lane, path, or fire road may only be viable as a route for emergency vehicles and inappropriate to use for evacuees. The strategy is envisioned as building off existing paths and fire roads rather than constructing a brand-new route.

Similar to the prior strategy, this strategy requires careful access management design that prevents access to personal vehicles during normal periods, but which can be removed to allow emergency vehicle access, as necessary.

Implementation Needs:

Prior to Implementation:

- Identify existing bike lanes, path, and fire trails that have potential for emergency vehicles to access and travel on.
- Review characteristics of the facility to identify if the route would be appropriate for conversion, including:

[7] Caltrans, "State Route 67 Highway Improvement Projects", https://dot.ca.gov/caltrans-near-me/district-11/current-projects/sr67-corridor/improvements

- Provides a substantial benefit for emergency vehicles or evacuees.
- Width of facility can accommodate emergency vehicles.
- Grade change is either appropriate for vehicles or could be accomplished through reasonable efforts (e.g., can be modified on a short timeline, through available funding, etc.).
- Maintenance is manageable (e.g., appropriate staff and funding is available).

During Implementation:

- Convert path or fire road into evacuation route (e.g., widening, paving, gates, etc.) for emergency vehicles. Adding, as necessary, additional access management to prevent personal vehicles from using facilities during normal periods.

Limitations:

- Cost-intensive strategy and potential for substantial land acquisition costs.
- Existing facilities may be managed by an assortment of agencies, including the City of Sonora, Tuolumne County, Chicken Ranch Rancheria of Me-Wuk Tribe, Tuolumne Band of Me-Wuk Tribe, USFS, and private owners. Coordination with land owners may be required if routes need to be modified or land needs to be acquired.

Case Studies:

- The District of Makenzie Community Wildfire Protection Plan notes that recreation trails can be constructed to support fire ground crews by building trails to a standard that support ATVs and installing gates and other barriers to manage access to unauthorized uses.[8]
- A cycletrack installed in London, UK was constructed to create a safe route for cyclists on the roadway. Although not designed for emergency access, the facility was sufficiently wide to support use by emergency vehicles to avoid congestion on the parallel road. [9]

3.4 BUILD / UPGRADE EXISTING ROAD TO STANDARD NEEDED FOR EVACUATION

Description: An engineering strategy that includes adding new roads or upgrading roadways to support evacuation activities. This strategy is similar to the strategy Maintain Road and Shoulder Clearance program in that the intention is to create a more connected roadway network for evacuations. The difference is that the previous strategies target existing roadways where maintenance would allow for use of the road for evacuation. This strategy is a more capital-

[8] District of Makenzie Community Wildfire Protection Plan 2017 Update: https://districtofmackenzie.ca/wp-content/uploads/2018/11/Mackenzie_2017_CWPP_Update-optimized.pdf
[9] *Think of Protected Cycleways as Priority Lanes for Ambulances*. https://www.forbes.com/sites/carltonreid/2020/07/07/think-of-cycleways-as-priority-lanes-for-ambulances/?sh=56b6f4a6e121

intensive strategy to install new or substantially alter existing roads, such as by expanding the width of the road.

Implementation Needs:

Prior to Implementation

- Identify locations with limited egress routes where improved maintenance or shoulder clearance is not sufficient to create alternative routes.

During Implementation:

- Select existing route or potential new route where roadway could be constructed.
- Design and construct route.

Limitations:

- Cost-intensive strategy and potential for substantial land acquisition costs. May also require coordinating with an assortment of agencies, including the City of Sonora, Tuolumne County, Chicken Ranch Rancheria of Me-Wuk Tribe, Tuolumne Band of Me-Wuk Tribe, USFS, and private owners.

GROUP 4 – IMPROVE DEVELOPMENT AND VULNERABLE AREA ACCESS

Group 4 includes strategies and treatments to reduce potential bottlenecks on roads serving residential developments and, as possible, increase the efficiency of evacuation routes.

4.1 ADD SECONDARY / ADDITIONAL ACCESS TO VULNERABLE COMMUNITIES

Description: Tuolumne County and CalFire have identified multiple small communities and developments where residents are served by one or two access points. In the event of a rapid evacuation, this could lead to congestion in the development or at locations where vehicles connect with a major roadway. In addition, a fire could more easily block access by closing the available evacuation route. Figure 5 shows the locations of communities along CA-108 that have been identified by CalFire or the County as having limited egress points.

Moving forward, State Bill 99 (SB 99), signed on August 30, 2019, requires jurisdictions to identify residential developments in hazard areas that do not have at least two evacuation routes upon the next revision of their housing elements.[10] Under the strategy, additional egress routes would be developed to serve evacuation. Where possible, the added access would allow for evacuation in a different direction in case a fire closes an available route.

Implementation

Prior to Implementation:

- Identify communities and locations with limited access and egress.

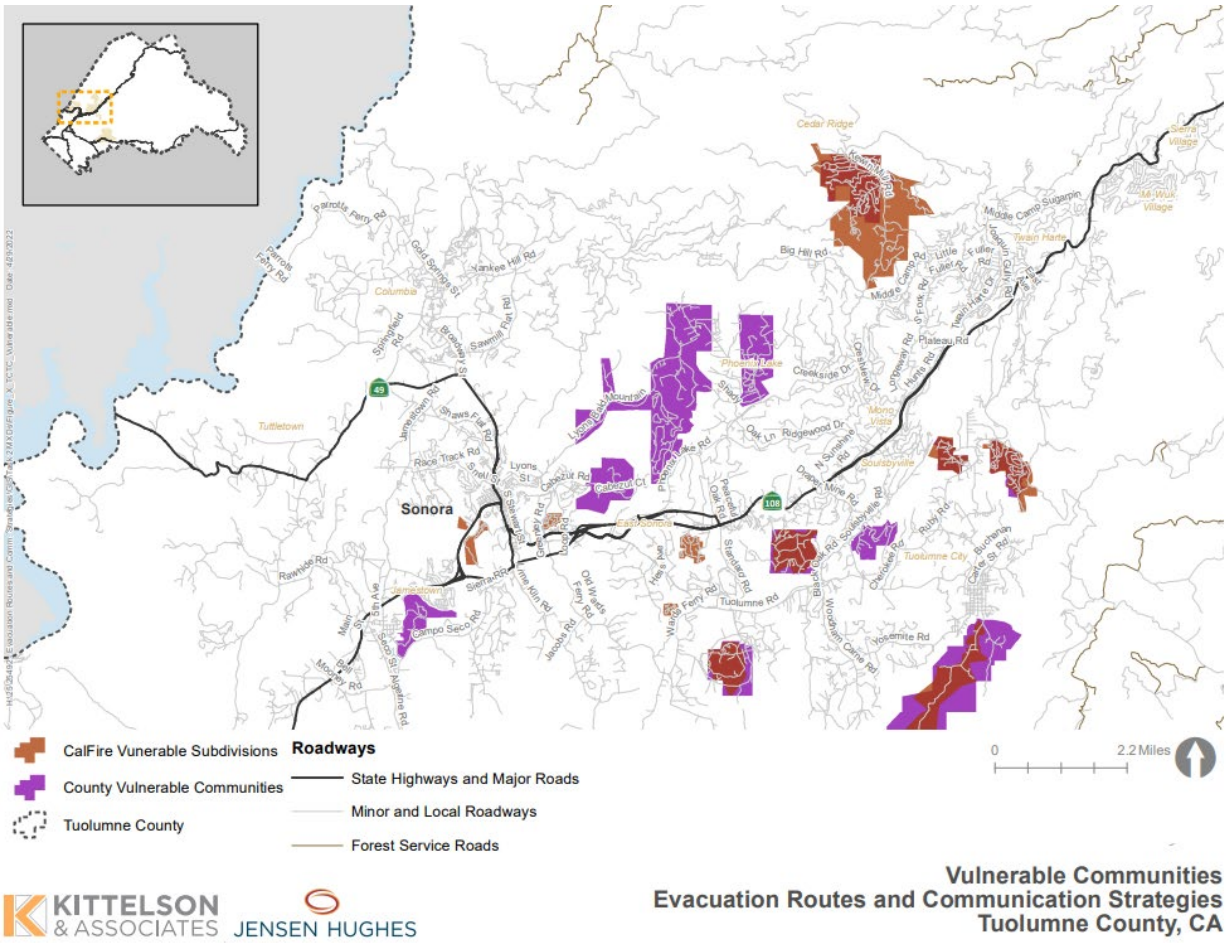
[10] https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201920200SB99

- Review potential locations where additional egress could be developed.

During Implementation:

- Option 1 – Construct new roadway access.
- Option 2 – Create a private access that would be available only in the event of a fire.
- Option 3 – Prepare a trail or other pathway that connects to locations where pick-up is possible.

Figure 5: Vulnerable Community Locations



Source: Kittelson & Associates, Inc. with data from CalFire and Tuolumne County

Limitations

- Geography may limit options for egress, such that secondary access would be to the same evacuation route. This would still add resilience and better distribute trips merging onto the evacuation route.
- Viable routes may require the acquisition of private property.
- Projects may be expensive and provide relatively little county-wide benefit.

- Routes only available during an evacuation may have access limitation that need to be removed during an evacuation, such as gates or bollards.

Case Studies:

- Debris blocked a road that serves as a single exit for a community during the 2017 Northern California Fire which resulted in residents being helicoptered to safety.[11]
- Access could be completed as pedestrian access. High Knob, a subdivision in the mountains of Virginia, developed an evacuation map that includes an evacuation route used as a defined trail. The evacuation route is for foot access only.[12]
- Kensington, CA has an designated evacuation route thorugh a cemetary. Normally the route is blocked by bollards that must be removed during an evacuation.[13]

GROUP 5 – GUIDANCE TO REDUCE ROADWAY DEMAND

Group 5 includes strategies to manage roadway capacity and communicate roadway conditions. Both strategies will be discussed in more detail as part of the communication and outreach tasks.

5.1 PHASED EVACUATION

Description: During an evacuation from a fire, it is critical to prioritize use of available roadway capacity for households who need additional time to evacuate and who are closest to the fire. In contrast, it is important to reduce congestion generated by individuals who are not in immediate risk. A survey of evacuees in three recent California fires found that 29% to 75% of households evacuated even though they did not receive a mandatory evacuation order.[14] These households include those that failed to receive an order due to a communication failure and those that chose to leave despite a relatively low risk. For the latter choice, these trips can generate downstream congestion that limit the movement of highest risk individuals.

Phasing an evacuation can help to optimize the use of available roadway capacity for serving the highest needs. Phasing can be implemented through communication strategies and through roadway operations, such as holding side-street access or routing non-critical evacuation through alternative routes where possible. In addition, the strategy could employ a "pre-stage" evacuation, encouraging visitors to leave before capacity must be marshalled for critical needs.

Implementation

Prior to Implementation:

- Develop communication plan with evacuation zones for staging evacuations. Include communcation to zones to identify a) zones that need to evacuate immediately, b) zones

[11] Wong, S., Broader J., Shaheen, S. (2020) "Review of Wildfire Evacuations from 2017 to 2019." 1-76. Available at: https://escholarship.org/content/qt5w85z07g/qt5w85z07g_noSplash_a1016d9a321138365ab7e2311309a373.pdf?t=q7c4sj
[12] https://www.hkoai.com/evacuating-to-safety
[13] https://www.kensingtonfire.org/files/66a907ac3/Kensington+Evacuation+Research+Project+Final.pdf
[14] https://escholarship.org/uc/item/5w85z07g

that need to be ready to evacuate with notice (i.e., zones on "stand-by"), and c) zones that do not need to evacuate.

- Develop an outreach plan to explain when to evacuate and potential restrictions to travel on side-streets.
- Identify locations with multiple evacuation routes, that could be rerouted to reserve capacity to maintain capacity for high-risk evacuees.
- Identify locations or populations where additional evacuation time is needed (e.g., medical facilities, low-car ownership areas, and elderly communities).

During Implementation:

- Communicate mandatory evacuation by evacuation zone.
- Limit or reroute non-critical evacuation by evacuation zone.
- Observe known bottlenecks to understanding ongoing capacity (ITS Strategies).

Limitations:

- Fast moving fires could overwhelm phased evacuation.
- Visitors may be less aware of the communication plan for evacuation and may be more likely to evacuate prior to mandatory evacuation.
- A strong desire of some visitors and residents to evacuate towards California and avoid non-direct evacuation routes (e.g., travel east out of Tuolumne County) can add congestion to the roadway network.
- Power outages or limited cell signals that hamper ability to communicate quickly.

Case Studies:

- Sonoma County assigns every area of the County to a pre-planned evacuation zone and then uses three emergency orders to manage evacuations.[15] One of the orders is "Shelter-in-Place" which is used both for when evacuation is impossible *and* if evacuation is unnecessary.
- Paradise Fire – Report found that due to a failure of communication systems, residents evacuated at the same time rather than a planned phased evacuation, leading to increased congestion that was exacerbated by fire impacting evacuation routes.[16]

5.2 INTELLIGENT TRANSPORTATION SYSTEM

[15] Know Your Zone – Sonoma County - https://sonomacounty.maps.arcgis.com/apps/instant/lookup/index.html?appid=58500b81c61148279263bed52403c81a

[16] (St. John and Serna, 2018; Serna et al., 2018)

Description: Good communication is critical during a fire, both for outreach to residents and visitors, and for coordinating activities among staff and emergency personnel. Real-time monitoring of travel conditions and disseminating travel information to evacuees (Highway Advisory Radio Systems (HAR), Dynamic Message Signs (DMS)) can be used during evacuations. The most common area of ITS application can be used for real-time monitoring of travel conditions. Several states, including South Carolina, Florida, and Louisiana, were either using or are planning to use remote traffic detection systems.

ITS are also planned to disseminate travel information to evacuees. Two of the systems planned for use are HAR and DMS. In contrast to traffic counter and CCTV systems that bring data in, HAR and DMS systems get information out. To make the most effective use of these tools (HAR has a limited range of about 3–5 miles), states were planning to use them in advance of exits and interchanges where services and alternative routes were available. The type of information conveyed through HAR and DMS included shelter locations, alternative evacuation routes, congestion, incident information, and services such as gas station, rest area locations, lodging availability, among others.

Implementation Needs:

Prior to Implementation:

- Implementation plan, including identifying roadways and intersections for ITS improvements.
- Available communication network connection.

During Implementation:

- Communicate updates through the system.
- Observe known bottlenecks to understanding ongoing capacity (ITS Strategies).

Limitations:

- Costs to implement ITS equipment is high and may be a barrier.
- Potential for equipment to be damaged by fire.

GROUP 6 – DEMAND MANAGEMENT

Group 6 includes strategies and treatments to manage demand and potential conflicts by closing or prohibiting use of roads or parking.

6.1 CLOSE ROADS / PROHIBIT STREET PARKING

Description: Identify roads and parking locations along major evacuation routes to close. This strategy could be implemented during high-risk conditions or during an evacuation. Closing roads is targeted towards limiting people from visiting high risk areas during evacuations. It could also be used to reserve roadway access for emergency vehicles. Prohibiting parking can support evacuation by limiting travel to a high-risk area or by reducing conflicts created by vehicles leaving or merging into traffic. Parking may also be prohibited where normal parking

activity may impede emergency vehicles from reaching critical infrastructure, especially on narrow roadways.

Implementation Needs:

Prior to Implementation:

- Identify conditions needed to close a road to the public and determine if there are unintended consequences from the closure. Identify roadways that could be closed without negatively impacting evacuees and emergency vehicles.
- Identify locations where prohibiting parking would support evacuation and post signs identifying potential parking restrictions.

During Implementation:

- Communicate which closures and prohibitions are in effect.
- Staff support to set up temporary closure of roads and on-street parking, including traffic control signs and gates.
- Communication and outreach to locations where visitors may be concentrated (e.g., campsites, resorts).

Limitations:

- Road closures could impact existing residents and may need to be established as only applying to visitors.
- Communication of the parking program would need to include a communication plan for visitors in Tuolumne County that may be unaware of roadway and parking restrictions and alternative routes.
- Program could conflict with normal parking behavior near trail heads and other outdoor destinations.
- Staff limitations may reduce the number of locations where the strategy can be implemented.

Case Studies:

- The City of Los Angeles maintains a "Red Flag" program for prohibiting parking on specific roads and locations.[17]
- The City of Oakland has previously closed multiple narrow high fire risk roads over the July 4th weekend to limit potential for fire ingition.

6.2 MANAGE OFF-STREET PARKING AT MAJOR TRIPS GENERATOR

[17] https://ers.lafd.org/redflag/

Description: Large trip-generating land uses can create substantial traffic. If those uses are located along or near a major evacuation corridor, traffic related to the land use could impede evacuation. Closing specific access or actively managing parking entrances to orient traffic away from evacuation routes could reduce potential for congestion, either by reorienting traffic or discouraging evacuees leaving and then reentering flow of traffic.

Implementation Needs:

Prior to Implementation:

- Identify large trip generating land uses and determine if specific parking plans could be developed that orient traffic away from known congestion points.
- Create a staffing plan to assist with parking and access management. This can include training staff at local businesses to manage parking and access.

During Implementation:

- Deploy staff to help implement closures or management processes.

Limitations:

- Closing parking lots and reorienting traffic may require coordination with local businesses.
- May create confusion or opposition from residents and businesses impacted by changes.
- Staffing limitations may reduce the number of locations where the strategy can be implemented.

6.3 TOW TRUCK AVAILABILITY

Description: Crashes or other vehicle breakdowns quickly impede the flow of traffic. As a result, having tow-trucks or other support vehicles strategically located is greatly beneficial for quickly identifying and responding to evacuation events. In Tuolumne County, roadways are already often limited to two lanes, such that road blockages must be resolved quickly. This strategy can be combined with ITS and other communication plans to ensure information about events is communicated rapidly.

Implementation Needs:

Prior to Implementation:

- Identify locations where tow trucks can be stationed to easily access evacuation routes (e.g., parking lots, pull outs, rest stops).
- Identify locations where capacity issues are more likely to occur or where it is more difficult for teams to access stopped vehicles.

During Implementation:

- Deploy tow truck teams proactively to cover evacuation routes and respond to issues as they arise.

Limitations:

- Roadways in Tuolumne County are often only two lanes without a shoulder, such that vehicles are difficult to pass once stopped. Additional lanes may need to be constructed or adjacent roadways identified for tow trucks to travel.

Case Study:

- Bulldozers were used to remove abandoned vehicles during the Camp Fire.

CONCLUSION AND NEXT STEPS

This memorandum describes a set of strategies identified for improving the capacity and resilience of the county roadway network to support potential future evacuation events. The strategies were identified based on previous congestion and evacuation studies, review of recent evacuation efforts, and staff feedback. A list of additional research and references that support or provide examples for the strategies begins on the following page. After completing the modeling of the six evacuation scenarios, the strategies will provide a basis for developing concepts for potential evacuation resiliency improvements at priority locations identified as having limited capacity during one of the evacuation scenarios.

ADDITIONAL REFERENCES

This section lists additional research and references for operational, engineering, and communication strategies for evacuation scenarios.

5.1 REVERSIBLE LANE/CONTRAFLOW

- Zhao, B., & Wong, S. D. (2021) "Developing transportation response strategies for wildfire evacuations via an empirically supported traffic simulation of Berkeley, California." Transportation research record, 2675(12), 557-582. Available at: https://escholarship.org/content/qt70p6k4rf/qt70p6k4rf.pdf

1.2 EMERGENCY SHOULDER USEAGE

- Caltrans State Route 67 Highway Improvement Project: https://dot.ca.gov/caltrans-near-me/district-11/current-projects/sr67-corridor/improvements
- Jannace, E. M. (2019) "Mass Evacuation Effects on Transportation: A Comparative Analysis," Beyond: Undergraduate Research Journal: Vol. 3 , Article 4. Available at: https://commons.erau.edu/beyond/vol3/iss1/4

2.1 SIGNAL COORDINATION – GREEN CARPET

- Chen, M., Chen, L., & Miller-Hooks, E. (2007) "Traffic signal timing for urban evacuation." Journal of urban planning and development, 133(1), 30-42. Available at: https://drum.lib.umd.edu/bitstream/handle/1903/2951/umi-umd-2744.pdf?sequence=1&isAllowed=y
- Parr, S. A., Kaisar, E. I., & Stevanovic, A. (2014) "Application of transit signal priority for no-notice urban evacuation." Natural Hazards Review, 15(2), 167-170. Available at: https://www.researchgate.net/profile/Aleksandar-Stevanovic/publication/273746115_Application_of_Transit_Signal_Priority_for_No-Notice_Urban_Evacuation/links/555d3a9408ae86c06b5d730d/Application-of-Transit-Signal-Priority-for-No-Notice-Urban-Evacuation.pdf

2.2 SIGNAL COORDINATION – DYNAMIC FLASHING YELLOW

- Asamoah, C. A. (2014). Dynamic flashing yellow for emergency evacuation signal timing plan in a corridor: Semantic scholar. Undefined. Retrieved May 4, 2022, from https://www.semanticscholar.org/paper/Dynamic-flashing-yellow-for-emergency-evacuation-in-Asamoah/f896455e97acf37f0cd01cc5f3bbb1ddbb79fc29

3.1 MAINTAIN ROAD AND SHOULDER CLEARANCE PROGRAM FOR SECONDARY ROADS

- Caltrans Roadside Fire Fuels Reduction: https://dot.ca.gov/programs/maintenance/roadside-fire-fuels

4.1 ADD SECONDARY / ADDITIONAL ACCESS TO VULNERABLE AREAS

- Wong, S.D., Martin, I., Halpem J. (2020) "Kengsington Evacuation Research Project" 1-101. Available at: https://www.kensingtonfire.org/files/66a907ac3/Kensington+Evacuation+Research+Project+Final.pdf

5.1 PHASED EVACUATION

- Zhao B, Wong SD. Developing Transportation Response Strategies for Wildfire Evacuations via an Empirically Supported Traffic Simulation of Berkeley, California. Transportation Research Record. 2021;2675(12):557-582. Doi:10.1177/03611981211030271. Available at: https://journals.sagepub.com/doi/full/10.1177/03611981211030271?casa_token=lgNDU4hGkwMAAAAA%3AZzWARtRBx4zFakxK1SEruWJolCoAEtGRvrWaV66jmQ0Fzi6JMSpKFTBeHhzU6PmGS6__-xa1IgE
- Chen, X., Zhan, F.B. (2014). Agent-based modeling and simulation of urban evacuation: relative effectiveness of simultaneous and staged evacuation strategies. In: Taylor, S.J.E. (eds) Agent-Based Modeling and Simulation. The OR Essentials series. Palgrave Macmillan, London. https://doi.org/10.1057/9781137453648_6
- Town of Moraga Evacuation Plan Zones. Available at: http://police.moraga.ca.us/documents/Evacuation%20Plan%20Zones.pdf

5.2 INTELLIGENT TRANSPORTATION SYSTEM

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