ATTACHMENT D

CITY OF OAKLAND

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August 4, 2023

Via E-mail

Shannan West
Housing Accountability Unit Chief
State of California Business, Consumer Services and Housing Agency
Department of Housing and Community Development
Division of Housing Policy and Development
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Sacramento, CA 95833

RE: City Response Letter Following HCD's Review of Oakland's Accessory Dwelling Unit (ADU) Ordinance under State ADU Law (Gov. Code, § 65852.2 et seq.)

Dear Shannan West:

Thank you for your review and the July 5, 2023 technical assistance letter (HCD Letter), on behalf of the California Department of Housing and Community Development (HCD), following the City of Oakland (City) submittal of its Accessory Dwelling Unit (ADU) Ordinance No. 13667 (Ordinance), which the City adopted January 18, 2022.

Please consider this response letter (Response Letter) the City's timely reply to the HCD Letter, which Government Code section 65852.2(h)(2)(A) requires within thirty (30) days of the HCD Letter, or by August 4, 2023.

Since the City received the HCD Letter immediately prior to the City Council adjourning for its summer recess, City Staff and the City Attorney's Office have not had an opportunity to confer with members of the City Council regarding this Response Letter. Therefore, this Response Letter may be subsequently amended following our meeting(s) with members of the Council, since it is solely within the Council's purview to determine whether to amend the Planning Code. In other words, it is not the intent of City staff to usurp Council's authority to make certain Planning Code amendments, or pre-commit the Council to a certain course of legislative action inasmuch as City Staff does not have the delegation of authority to do so outside Council authorization.

In addition to Council approval, the legislative process will require that City Staff bring any Planning Code amendments to the Planning Commission and Community and Economic Development Committee (CED) of the Council in their roles as advisory/recommending bodies to the Council. Once the item is brought before Council, the Planning Code amendments require two readings (two separate Council meetings), as required for enactments of City ordinances under the City Charter.

In addition, the City is hereby requesting the opportunity to meet and confer with HCD staff to discuss certain comments in the HCD Letter. The City specifically requests the opportunity to meet and confer in its response to specific HCD comments.

During the meet and confer and legislative process, the City commits to regularly update HCD as to the City's Planning Code amendment process. For example, the City will provide regular updates to HCD: (1) as to when the City will bring forward Planning Code amendments for Planning Commission recommendation and City Council adoption that comply with an HCD comment, and/or (2) whether the City plans to re-adopt certain Planning Code provisions with findings that further explain why the City believes the Planning Code provision(s) comply with State law. Of course, the City may adopt Planning Code amendments in response to certain HCD comments, while also adopting findings, with no Planning Code revisions, in response to other HCD comments if the City disagrees with HCD's comment and consensus cannot be reached. We will also keep you updated on the City's legislative schedule as we work with you through HCD's comments. While we still need to confer with Planning Commissioners and Councilmembers, we anticipate being able to complete the legislative process by early 2024.

Finally, City staff would like to thank you for confirming that the Ordinance addresses many statutory requirements, even if HCD believes the Ordinance does not comply with State ADU Law in some respects.

Below are the City's individual responses to each of HCD's comments. As to those aspects of the Ordinance where HCD believes the City is not in compliance, the City looks forward to continued collaboration with HCD to reach a result that addresses the housing crisis, fairly interprets State law, and protects public safety.

- **HCD Comment**: . . . . while HCD is sympathetic to concerns about fire safety and the need to ensure adequate evacuation in the event of a fire, the City has not adequately demonstrated that new ADUs will impact public safety in the VHFHSZ. The findings as presented in 17.88.020 feature no data and refer more to vehicle use and evacuation than housing, while mentioning a Local Hazard Mitigation Plan that "points out existing vulnerable and isolated populations in VHFHSZ areas" and a Vegetation Management Report that "underscores the fact that the area within the VHFHSZ is susceptible" to wildfires. Note that the VHFHSZ mapping was not intended to serve as a development moratorium. Rather, according to Cal Fire, these maps are intended to be used for planning purposes and mitigation measures such as building material requirements and zones of defensibility around structures.

Given the City's attention to vehicle use as being a primary concern, the City does not account for the potential for ADUs to be excluded from requiring a parking space given the availability of public transit in the S-9 overlay. For example, Map 18 at the end of Appendix A shows several large sections of the S-9 overlay South of Piedmont; each of these areas is well served with bus stops for the 646, 652 and 682 bus lines within a half-mile walk. All such areas would not be required to provide parking spaces. Furthermore, occupancy of an ADU does not necessarily guarantee the presence of another car on a lot.

Per State ADU Law, ADUs are permitted in all areas zoned for residential and mixed use, and a local agency may, by ordinance, designate areas for the creation of ADUs based on the adequacy of water and sewer services and the impact of accessory dwelling units on traffic flow and public safety (Gov. Code, § 65852.2, subd. (a)(1)(A)). However, local jurisdictions may not preclude the creation of categories of ADUs altogether. In this situation, any limits on where ADUs are permitted based on the impacts of public safety should be accompanied by detailed findings of fact explaining why ADU limitations are required and consistent with these factors.

Lastly, even if the City provided adequate justification for this restriction on ADUs under Government Code section 65852.2, subdivision (a), the City may not justify a restriction, such as exists in Sections 17.88.050 (A)(1), (A)(2) and (A)(3) on ADUs created under subdivision (e). Local development standards (such as an area restriction based on VHFHSZ designation) provided by the Ordinance pursuant to Government Code section 65852.2, subdivisions (a) through (d), do not apply to ADUs created under Government Code section 65852.2, subdivision (e). Therefore, the City must ministerially permit units created pursuant to subdivision (e).

- **City Response:** The City relied on more than just the findings in Oakland Municipal Code (O.M.C.) Section 17.88.020. In fact, the City relied on data in the Ordinance's legislative package regarding the already significant issue of housing density and the lack of evacuation safety in Very High Fire Severity Zone (VHFSZ), and specifically a significantly narrower S-9 Overlay Zone where the risks for public health and safety are amplified even further. For example, the Ordinance's legislative package contained the following documents:
    - City of Oakland Zonehaven Model Evacuation of an Event Similar to the 1991 Oakland Firestorm Under Current Conditions (*See* **Attachment A**);
    - Excerpts from the Draft Oakland Hazard Mitigation Plan (2021-2026) (*See* **Attachment B**);
    - City of Oakland Wildfire Prevention Planning Report (*See* **Attachment C**);
    - Excerpts from the Draft Oakland Vegetation Management Plan (*See* **Attachment D**);
    - City Administrator Letter to Planning Director Bill Gilchrist (*See* **Attachment E**);
    - Oakland Fire Department Letter In Support of Restrictions for ADUs (*See* **Attachment F**); and
    - UC Berkeley Study: *Developing Transportation Response Strategies for Wildfire Evacuations via an Empirically Supported Traffic Simulation of Berkeley, California* (*See* **Attachment G**).

Each of the above documents contain data and supporting evidence that show housing density in the Oakland hills (or, similarly, the Berkeley hills) presents very unique public safety challenges in the event of an emergency evacuation or ambulance/fire response.

For example, the Oakland Firestorm of 1991 is a grim reminder of the tragedy that can take place in the Oakland hills when people attempt an emergency evacuation. The Zonehaven Model shows how current housing density in this area is already at unmanageable levels for emergency response, even without additional density. If each single-family parcel is ministerially permitted to have two ADUs and one JADU per parcel (three ADUs total), then emergency response will further exacerbate and already unsustainable evacuation scenario.

In addition, ADUs often do not require off-street parking, leaving people who reside in these units to park their cars illegally on the sides of already narrow, legally nonconforming roads in the S-9 Overlay Zone, where street parking is just not possible due to substandard road widths. HCD is incorrect that the S-9 Overlay Zone is adequately served by public transit. As stated below, the public transit lines HCD has cited are not even in operation.

City consultants have also warned City officials against increasing housing density in the Oakland hills. For example, in the Draft Oakland Hazard Mitigation Plan (2021-2026), Tetra Tech cited the “dense population” in the Oakland hills as a significant impact on evacuation. The Draft Oakland Hazard Mitigation Plan states:

> The Oakland WUI is fully built out, and evacuation in the event of a widespread fire can be restricted by a **dense population** attempting to leave the area in many vehicles at the same time. This can be compounded by narrow urban streets with parked cars creating barriers to evacuation. Planners and traffic engineers must look at the entire evacuation route. Most roads leading out of the City’s hills are one lane in each direction. This could inform mitigation strategies that address road infrastructure projects in the WUI.[1] (Emphasis Added.)

In addition, on November 19, 2019, the City Council adopted Resolution No. 87940 C.M.S., declaring Wildfire Prevention a top priority for the City of Oakland and requesting the City Administrator to present a comprehensive report to the Council’s Public Safety Committee (PSC) that addresses Oakland’s Wildfire Prevention Strategies. Specifically, The Council directed the City Administrator to:

> Submit a Report That Addresses: 1) How City Departments Will Address Wildfire Prevention In Their Planning, Programs And Projects For Oakland’s Wildland Urban Interface (WUI), Including The Extent To Which The Strategies Will Involve Multi-Disciplinary And Multi-Agency Teams In The Development Of

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[1] Tetra Tech prepared the Draft Local Hazard Mitigation Plan for the City. While **Attachment B** contains an excerpt of the Draft Local Hazard Mitigation Plan, City Staff provided the Planning Commission and Council a link to the entire Local Hazard Mitigation Plan, which is available at: https://cao-94612.s3.amazonaws.com/documents/2021-04-30_OaklandHMP_AgencySubmittalDraft_2021-05-13-231111_rlny.pdf

> Pre-Fire Plans, 2) What Wildfire Prevention Plans Will Include Such As Home Hardening, **Evacuation** And Other Wildfire Prevention Strategies For Both Private And Public Properties, And Public Communication Strategies, Before, During And After A Wildfire Event, And 3) The Extent To Which Wildfire Prevention Will Be Addressed In The Next Updates To The City's General Plan, Safety, Open Space, Hazard Mitigation Plans And Other Similar Plans.[2]
> (Emphasis Added.)

In summary, the Wildfire Prevention Planning Report concluded that housing density would need to be limited in the S-9 Overlay Zone and a comprehensive evacuation plan would need to be developed for those already living in these areas due to lack of road infrastructure and access to escape routes in the event of a fire. To address this issue, the Wildfire Prevention Planning Report states:

> [a] planning effort that is currently underway is writing the new ordinance to conform to the recently passed State Laws for accessory dwelling units (ADUs) and incorporating regulations restricting ADUs in the Very High Fire Hazard Severity Zone, which are included in the S-9 Fire Safety Protection Combining Zone. As part of writing the ADU ordinance, planning staff is coordinating with both OFD and OakDOT.

Similarly, the draft Oakland Vegetation Management Report was prepared to address vegetation management in the Oakland hills. Even though the report focuses primarily on vegetation management, City consultants advised the City that the current condition of "high housing density" and "congested roads during emergencies" presented significant challenges to the City in reducing wildfire risk to public safety.[3]

In light of these considerations, it is important that HCD understand that the Planning Commission and City Council were presented with evidence and data that pointed to the **current level of housing density** and lack of safe evacuation routes in the Oakland Hills. To add as much as three times, or more, of residential units to this area would put the public at greater substantial risk to the point where safe evacuation would not be reliable. The housing crisis is irrefutably a matter of primary concern for the State and the City: the ability of police, ambulance and fire units to protect Oakland residents wherever they are housed is also attendant in addressing this crisis and falls within the City's reserved powers and responsibility, which we must also incorporate into any plan or policy to provide housing.

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[2] The City of Oakland Wildfire Prevention Report was prepared by Joe Devries, Assistant City Administrator, in consultation with Oakland Fire Department, Oakland Police Department, Oakland Department of Transportation, the Planning and Building Department, Oakland Public Works, and outside agencies such as East Bay Municipal Utility District (EBMUD) and CalTrans.

[3] Dudek, with assistance from Horizon Water and Environment, prepared the Draft Vegetation Management Plan in consultation with the Oakland Fire Department. While Attachment D contains an excerpt of the Draft Vegetation Management Plan, City Staff provided the Planning Commission and Council a link to the entire Draft Vegetation Management Plan, which is available at: https://cao-94612.s3.amazonaws.com/documents/Oakland-VMP_Revised-Draft_NOV-1-2019.pdf

The HCD Comment references Map 18 at the end of Appendix A and claims it shows several large sections of the S-9 Overlay Zone south of Piedmont that are "well served with bus stops for the 646, 652 and 682 bus lines within a half-mile walk." Bus numbers 646 (Montera-Skyline), 652 (Montera-MacArthur) and 682 (Bishop O'Dowd High line) are school bus lines that run only during school times and are deployed for the purpose of serving as school transportation lines. None of these bus lines is currently active and there are no planned upcoming schedules for these bus lines.[4] As a result, residents in this and other areas in the S-9 Overlay Zone must rely on vehicular transportation to and from their primary residences and ADUs. This specific issue underscores the need for cities to play an active role in local hazard planning as cities face the effects of climate change.

Regarding local response to climate change, the California Office of Planning and Research (OPR) has provided guidance for local jurisdictions to address local hazards through their Local Hazard Mitigation Plans (LHMPs) and General Plan Safety Elements to respond to mounting climate change impacts.[5] Specifically, local governments are now required, in accordance with Senate Bill 379, Land Use: General Plan: Safety Element (Jackson, 2015) to include a climate change vulnerability assessment, measures to address vulnerabilities, and a comprehensive hazard mitigation and emergency response strategy. The City is tasked to confront the very real threat of wildfire including: the need for safe evacuation, unimpeded emergency response through emergency vehicle access, and the maintenance of clear space between structures.

Government Code section 65302(g)(3)(C)(iii) also requires the City to develop implementation measures for "[d]esigning adequate infrastructure if a new development is located in a state responsibility area or in a Very High Fire Severity Zone, including safe access for emergency vehicles, visible street signs, and water supplies for structural fire suppression." In furtherance of the City's responsibility to protect its residents, and in addition to the above referenced studies, the City is also in the process of developing its Safety Element as part of its Oakland 2045 General Plan.[6]

Chapter 2.2 of the Safety Element establishes the City's policies for addressing wildfires from climate changes and the risks to public safety. Specifically, Goal SAF-2.3 of the Draft Safety Element, entitled Development in the Very High Fire Hazard Severity Zone (VHFHSZ), sets forth a number of planning tools and mitigations for ensuring any development in the VHFHSZ does not exacerbate an already dangerous condition with respect to vehicular access and evacuation. Those planning tools and mitigations include:

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[4] The status of service for each line is listed on AC Transit's website as follows:
Line 646: https://www.actransit.org/bus-lines-schedules/646
Line 652: https://www.actransit.org/bus-lines-schedules/652
Line 682: https://www.actransit.org/bus-lines-schedules/682

[5] *See California Office of Planning and Research* General Plan Guidelines at Chapter 4: "Required Elements" *available at:* https://opr.ca.gov/planning/general-plan/guidelines.html.

[6] *See* the City of Oakland's Public Review Draft Safety Element for the Oakland 2045 General Plan, prepared by Dyett and Bhatia, Urban and Regional Planners, with contributions from Kittelson & Associates, Inc. and Environmental Science Associates, *available at*: https://cao-94612.s3.amazonaws.com/documents/Safety-Element_Public-Hearing-Draft_073123.pdf

> Prioritize development in areas with existing adequate road networks, evacuation routes, and water infrastructure. Require any new development in the Very High Fire Hazard Severity Zone to prepare a Fire Protection Plan that minimizes risks by:
>
> - Assessing site-specific characteristics such as topography, slope, vegetation type, wind patterns, etc. as part of a risk analysis.
> - Determination of fire response capability including the assistance of local fire protection agencies, and availability of local resources.
> - Siting and designing development to avoid hazardous locations (e.g., through community fire breaks) to the extent feasible.
> - Incorporating fuel modification and brush clearance techniques in accordance with applicable fire safety requirements (including fuel breaks and their maintenance) and carried out in a manner which reduces impacts to environmentally sensitive habitat to the maximum feasible extent. Using fire-resistant building materials and design features, such as visible signage, consistent with the adopted Oakland Municipal Code and Fire and Building Code standards (including Fire Safe Regulations as minimum standard).
> - Using fire-retardant, native plant species in landscaping.
> - Complying with established standards and specifications for fuel modification, visible home and street addressing and signage, defensible space, access and egress, and water facilities.
> - Banning fuel storage (e.g., fuel storage for power generators) in VHFHSZ.
> - Requiring street improvements to comply with minimum fire road access standards.
> - Disallowing new residential development/subdivisions in areas with less than two evacuation routes (as shown in Figure SAF-13b), unless a development were to be able to provide additional connections to ameliorate this condition.
> - Following the most recent California Fire Code as adopted and amended.
> - Participating in the City's fire safety and public education efforts related to requirements for development, property maintenance, and emergency preparedness.
>   (City's Public Review Safety Element, p. 2-13; Emphasis Added.)

By ministerially permitting three new dwelling units per lot in the VHFHSZ (and specifically the S-9 Overlay Zone where road networks are already too narrow and unsafe), the City would be ignoring or vitiating critical planning approaches and mitigation that its consultants listed in its Draft Safety Element. As a result, it would require the City to: (1) ignore or vitiate its state-mandated duty under the Safety Element and (2) place its residents in these areas at substantial risk due to lack of emergency vehicle access, lack of means of egress, and lack of appropriate fire mitigations for new development. Simply put, permitting ADUs at HCD's required density would expose residents to injury and death in the event of a wildfire or catastrophic emergency.

This point is especially underscored by the fact that the S-9 Overlay Zone was created to highlight an area in Oakland where roads are already substandard under the O.M.C. As City Staff cited in its staff report to the Planning Commission, roads in the S-9 Overlay Zone violate road width standards.[7] The City requires a minimum road width of 20 feet to enable emergency vehicle access. This standard is already not being met on many of the roads in the S-9 Overlay Zone.

With these real operational concerns and street standard in mind, the City respectfully requests that HCD and the City meet and confer on this HCD Comment so that: (1) HCD can better understand the local constraints the City faces in housing density and evacuation management in the S-9 Overlay Zone and (2) the City may have an opportunity to collaborate with HCD to develop a feasible solution that complies with State law, encourages housing, and protects public safety.

- **HCD Comment:** 17.09.040 (A) – *JADU Definition* – The Ordinance prohibits JADUs "as a conversion of detached or attached accessory structures." However, Government Code section 65852.22, subdivision (a)(4), states that an ADU Ordinance must "[r]equire a permitted junior accessory dwelling unit to be constructed within the walls of the proposed or existing single-family residence. For purposes of this paragraph, enclosed uses within the residence, such as attached garages, are considered a part of the proposed or existing single- family residence." Therefore, the City must allow for the conversion of enclosed uses within the residence, such as attached garages.

- **City Response:** The City acknowledges this HCD Comment and will recommend the Council approve a Planning Code amendment that allows for the conversion of enclosed uses within the residence, such as attached garages.

- **HCD Comment:** 17.30.140 and 17.102.270 – *Additional Kitchen* – The Ordinance states, "No residential facility shall be permitted to have both an additional kitchen… and [an] ADU." However, the presence of an additional kitchen cannot preclude the ministerial approval of an ADU that conforms to Government Code section 65852.2, though the presence of an ADU may preclude the creation of an additional kitchen. The City must note the exception.

- **City Response:** The City acknowledges this HCD Comment and will recommend the Council approve a Planning Code amendment that makes it clear that the existence of an additional kitchen does not preclude an ADU. However, the City requests to meet and confer with HCD to determine whether the City may require the removal of the additional kitchen if it is not being used within the ADU or JADU and is not necessary for the primary residence. The City would be concerned about a primary dwelling containing two kitchens and additional kitchen(s) as part of an ADU and/or JADU.

- **HCD Comment:** 17.33.040, Table 17.33.02 (L1) – *Existing Primary Dwellings* – The Ordinance states that in the Neighborhood Center Commercial Zone, ADUs "are permitted when there is an existing One-Family Dwelling on a lot…." The table appears to permit the development of two-family and multifamily dwellings as well. Per

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[7] September 1, 2021 Oakland Planning Commission Staff Report, Case File ZA21006, **Attachment C**, which is *available at:* https://www.oaklandca.gov/meeting/september-1-2021-planning-commission-meeting.

Government Code section 65852.2, subdivision (a)(1)(D)(ii), ADUs must be ministerially approved on any lot "zoned to allow single-family or multifamily dwelling residential use and includes a proposed or existing dwelling." The Ordinance omits mention of proposed single-family dwellings and existing or proposed multifamily dwellings. The City must amend the language to comply with statute.

- **City Response:** The City requests to meet and confer with HCD as to permitted uses in the Neighborhood Center Commercial Zone (CN Zone). Within the CN Zone, **existing** Single-Family and Two-Family Dwellings are permitted; however, **new** Single-Family or Two-Family Dwellings are not permitted. For this reason, ADUs are permitted for **existing** Single-Family and Two-Family Dwellings, but not for those that are proposed because those uses – if proposed -- are prohibited in the CN Zone. The CN Zone does permit both existing and proposed Multifamily Dwellings, so the City will recommend the Council adopt a Planning Code amendment requiring ADUs in existing or proposed Multifamily Dwellings.

- **HCD Comment:** 17.88.050 (B)(1) – *Fire Safety Parking Compromise* – The Ordinance allows for alternative ADU development options in the S-9 Fire Overlay if "[a]t least one additional off-street parking space is created on the lot for the ADU in addition to any regularly required off-street parking spaces for the primary residential facility. Also, any lost parking spaces must be replaced on the lot…." The concern with the S-9 Overlay has previously been discussed. However, Government Code section 65852.2, subdivision (d), prohibits requiring parking when any of the following apply:

  - The ADU is located within one-half mile walking distance of public transit. (Gov. Code, § 65852.2 (d)(1).)
  - The ADU is located within an architecturally and historically significant historic district. (Gov. Code, § 65852.2 (d)(2).)
  - The ADU is part of the proposed or existing primary residence or an accessory structure. (Gov. Code, § 65852.2 (d)(3).)
  - On-street parking permits are required but not offered to the occupant of the ADU. (Gov. Code, § 65852.2 (d)(1)(d).)
  - A car share vehicle is located within one block of the ADU. (Gov. Code, § 65852.2 (d)(5).)

  Furthermore, pursuant to Government Code section 65852.22, subdivision (b)(1), a parking space may not be required under any circumstance for a JADU. Therefore, the City must remove this section.

- **City Response:** As discussed above, the City requests to meet and confer with HCD on a comprehensive and common-sense strategy for addressing public safety and safe parking, traffic, and evacuation strategies in the S-9 Overlay Zone. Nevertheless, City Staff also would like to meet and confer with HCD on their comment regarding parking requirements for JADUs. The Ordinance already exempts parking for JADUs so the City seeks clarity on this comment.

- **HCD Comment:** 17.103.080 (A)(3) – *Separate Sale* – The Ordinance currently prohibits the separate sale of an ADU or junior accessory dwelling unit (JADU). However, Government Code section 65852.26 creates a narrow exception to allow separate conveyance of an ADU to a qualified buyer if the property was built or developed by a qualified nonprofit corporation, among other things. The City should update the Ordinance to cite the exception.

- **City Response:** City Staff will recommend the Council adopt a Planning Code amendment that creates an exception to allow separate conveyance of an ADU to a qualified buyer if the requirements of Government Code section 65852.26 are met.

- **HCD Comment:** 17.103.080 (A)(9) – *Exterior Visibility* – The Ordinance states that “an exterior stairway proposed to serve an ADU or JADU on a second story or higher shall not be visible from the front public right of way. However, local development standards provided by the Ordinance pursuant to Government Code section 65852.2, subdivisions (a) through (d), do not apply to ADUs created under Government Code section 65852.2, subdivision (e), which applies to converted units created on the second floor. Furthermore, as statute for both ADUs and JADUs require independent entry into the unit, a constraint on the location provisions necessary for independent entry may prohibit the creation of an additional housing unit. (Gov. Code, § 65852.2, subd. (e)(1)(A)(ii) (Gov. Code, § 65852.22, subd. (a)(5)) Therefore, the City must amend the Ordinance to clarify that the exterior stairway must not be visible when feasible.

- **City Response:** City Staff will recommend that the Council adopt a Planning Code amendment that clarifies that the exterior stairway must not be visible, when feasible.

- **HCD Comment:** 17.103.080 (A)(10)(a) and (10)(b) – *Oakland Cultural Heritage Survey* – The Ordinance creates special restrictions for ADUs in “structures rated ‘A’, ‘B’ or ‘C’ by the Oakland Cultural Heritage Survey. Government Code section 65852.2, subdivision (a)(1)(B)(i), states that local jurisdictions may, "Impose standards on accessory dwelling units that… prevent adverse impacts on any real property that is listed in the California Register of Historic Resources." State statute does not acknowledge *local* registers. Therefore, the City must remove these sections.

- **City Response:** City Staff will recommend that the Council adopt a Planning Code amendment that removes special restrictions for ADUs in “structures rated ‘A’, ‘B’, or ‘C’ by the Oakland Cultural Heritage Survey.” City Staff will recommend that the Council adopt a Planning Code amendment that imposes standards on ADUs that prevent adverse impacts on any real property that is listed in the California Register of Historic Resources.

- **HCD Comment:** 17.103.080 (A)(12) – *Landscaping Standards* – The Ordinance requires trees to be planted for every ADU developed, with larger units requiring more trees. However, Government Code section 65852.2, subdivision (a)(5), states, “No other local ordinance, policy, or regulation shall be the basis for the delay or denial of a building permit or a use permit under this subdivision.” Therefore, ADU approval cannot be made contingent on planting trees. Moreover, local development standards provided by the Ordinance pursuant to Government Code section 65852.2, subdivisions (a) through (d), do not apply to ADUs created under Government Code section 65852.2, subdivision (e). While the City may award voluntary tree planting by providing incentives, it may not make it a requirement. The City might consider creating or modifying incentive programs to encourage tree planting. Accordingly, the City must either remove the tree planting requirement from the Ordinance or clarify it as an incentive.

- **City Response;** City Staff will recommend that the Council adopt a Planning Code amendment that clarifies that the ADU applicant may either: (1) receive additional incentive(s) if the applicant plants a tree, and/or (2) that the planting of a tree in conjunction with an ADU or JADU is voluntary.

- **HCD Comment:** 17.103.080 (A)(15)(c) – *Limited Amnesty Clause* – The Ordinance states "The Planning Code amnesty and enforcement delay programs provided in this Section are available to any property owner whose Unpermitted Accessory Dwelling Unit meets the program requirements provided within this Section." However, Government Code section 65852.23, subdivision (a), states "(a) Notwithstanding any other law… a local agency shall not deny a permit for an unpermitted accessory dwelling unit that was constructed before January 1, 2018, due to either of the following: (1) The accessory dwelling unit is in violation of building standards pursuant to Article 1 (commencing with Section 17960) of Chapter 5 of Part 1.5 of Division 13 of the Health and Safety Code. (2) The accessory dwelling unit does not comply with Section 65852.2 or any local ordinance regulating accessory dwelling units." The City's amnesty program has a narrower scope than state statute requires, as an ADU permit may not be denied for units created prior to January 1, 2018, even if it conflicts with building code standards, local development standards, or Government Code section 65852.2. Therefore, the City must amend the Ordinance to comply with statute.

- **City Response:** It appears that Government Code section 65852.23 was recently added on January 1, 2023 through the passage of SB 897. As such, City Staff will recommend that the Council adopt Planning Code amendments making clear that the City shall not deny a permit for an unpermitted ADU that was constructed before January 1, 2018 due to either of the following: (1) the ADU is in violation of the building standards pursuant to Article 1 (commencing with Section 17960) of Chapter 5 of Part 1.5 of Division 13 of the Health and Safety Code, or (2) the ADU does not comply with Section 65852.2 or any local ordinance regulating ADUs.

  However, City Staff requests to meet and confer with HCD to clarify that City Staff will also recommend to the Council that the City may "deny a permit for an ADU subject to the above if the City makes a finding that correcting the violation is necessary to protect the health and safety of the public or occupants of the structure." In addition, City Staff will recommend the Council clarify that Government Code section 65852.23 does not apply to a building that is deemed substandard pursuant to Section 17820.3 of the Health and Safety Code.

- **HCD Comment:** 17.103.080 (A)(15)(f) – *Amnesty Clause & S-9* – The Ordinance exempts units built in the S-9 Overlay from the amnesty program. As the concerns with the S-9 Overlay have already been discussed, exempting units in this area for an amnesty program intended for all applicable unpermitted ADUs exceeds state statute. The City must remove this reference.

- **City Response:** City Staff requests a meet and confer with HCD regarding this comment. State law permits the City to find an unpermitted ADU ineligible for amnesty if "correcting the violation is necessary to protect the health and safety of the public or occupants of the structure." For all of the reasons already discussed above, the City has grave concerns about the life safety of occupants in the S-9 Overlay Zone, in terms of: (1) the ability to evacuate from the area in an emergency and access for Emergency services to reach residents suffering an emergency, (2) provision and maintenance of defensible space and building separations, and (3) building standards related to fire and life safety. In other words, State law permits local agencies to make life safety findings under Government Code section 65852.23 that would make an ADU ineligible for the Amnesty Program.

- **HCD Comment:** 17.103.080 (A)(15)(h) – *Expiration Clause* – The Ordinance conditions the amnesty clause with "The Planning and Building Director or his or her designee shall not approve any applications for the Planning Code amnesty request or Building Code enforcement delay on or after January 1, 2030." However, Government Code section 65852.23 has no condition for expiration. Therefore, the City must remove this section.

- **City Response:** City Staff will recommend that the Council adopt a Planning Code amendment removing this section. Government Code section 65852.23 was added after the City adopted the Ordinance, so this will serve to simply update the Ordinance with a recent change to State law.

- **HCD Comment:** 17.103.01, Table A, Note 1 – *Unit Mixture* – The Ordinance states that "A Category One or Category Two ADU may be combined on the lot with one (1) JADU. However, a lot may not contain both a Category Two ADU and a Category One ADU. A lot with a One-Family Facility may only contain two ADUs if one (1) is a JADU." This forces a developer or homeowner to choose either a converted unit or a detached new construction unit. However, Pursuant to Government Code section 65852.2, subdivision (e)(1), "Notwithstanding subdivisions (a) to (d), inclusive, a local agency shall ministerially approve an application…to create any of the following: (A) One accessory dwelling unit and one junior accessory dwelling unit per lot with a proposed or existing single- family dwelling…(i) The accessory dwelling unit or junior accessory dwelling unit is within the proposed space of a single-family dwelling or existing space of a single-family dwelling or accessory structure." Moreover subpart (B) permits "One detached, new construction, accessory dwelling unit that does not exceed four-foot side and rear yard setbacks." The use of the term 'any" followed by an enumeration of by-right ADU types permitted indicate that any of these ADU types can be combined on a lot zoned for single family dwellings. The Legislature, in creating the list did not use "or" nor "one of" to indicate only one or another would be applicable to the exclusion of the other.

  Thus, if the local agency approves an ADU that is created from existing (or proposed) space of a single-family dwelling, or created from an existing accessory structure, and the owner subsequently applies for a detached ADU permit (or vice versa), which meets the size and setback requirements, pursuant to the subdivision, the local agency cannot deny the applicant, nor deny a permit for a JADU under this section. This permits a homeowner, who meets specified requirements, to create one (1) converted ADU, one (1) detached, new construction ADU, and one (1) JADU, in any order without prejudice, totaling three units. This standard simultaneously applies to ADUs created pursuant to Government Code section 65852.2, subdivision (e)(1)(C) and (D), on lots with proposed or existing multifamily dwellings according to specified requirements. Therefore, the City must revise the table and remove the note to establish the allowable unit combination.

- **City Response:** City Staff will recommend that Council adopt a Planning Code amendment that revises the table to remove the note to establish the allowable unit combination. The City notes that this appears to be a shift from a prior HCD interpretation that subdivision (e) required two ADUs per lot, which the City relied upon in initially creating these tables. The fact that three ADUs (one conversion ADU, one JADU, and one detached ADU) may be approved per single-family lot only further underscores the gravity of the threat of increased population density on narrow and circuitous roads in the S-9 Overlay Zone. In addition, the State law apparently does not require off-street parking for these ADUs, even though the S-9 Overlay Zone is severely underserved, or not served at all as described above, by public transit. This will have disastrous consequences for fire evacuation in the S-9 Overlay Zone, both in terms of number of people needing to evacuate and vehicular congestion, both from anticipated on-street parking and vehicle delay on already narrow roadways.

- **HCD Comment:** Tables 17.103.01 and 17.103.02 – *Converted Size Limitations* – The Ordinance creates size limitations for converted units within the primary and accessory structures for both single-family and multifamily buildings. However, size maximums do not apply to converted units, as local development standards provided by the Ordinance pursuant to Government Code section 65852.2, subdivisions (a) through (d), do not apply to ADUs created under subdivision (e), and only new construction detached in subdivisions (e)(1)(B) and (e)(1)(D) have a discrete size limit stated therein. The City must note the exception.

- **City Response:** City Staff will recommend that the Council adopt a Planning Code amendment noting the exception that there are no size limitations for converted units within the primary and accessory structures for single-family and multifamily buildings. However, City Staff requests to meet and confer with HCD prior to this recommendation to determine whether this creates a loophole where a property owner can create an oversized accessory structure, in some cases bigger than -- or the same size as -- the primary structure, and then simply convert the accessory structure to an ADU. City Staff is curious how that loophole is consistent with the general 1,200 square foot size limitation the City may impose on ADUs in Government Code section 65852.2(a)(1)(D)(v). While Government Code section 65852.2(e)(1)(A) does not apply a size limitation, it also does not prevent the City from applying the 1,200 square foot size limitation set forth in State law. The City questions whether HCD is too broadly applying the subdivision (e) preemption of subdivisions (a) through (d). This also appears to be a shift in HCD interpretation from the previous 2021 ADU Handbook.

- **HCD Comment:** Numerous References – *Height Limits* – The Ordinance refers throughout to a height maximum of sixteen feet for ADUs. However, Government Code section 65852.2, subdivision (c)(2)(D), sets ADU height maximums at 16, 18, and 25 feet, depending on the applicable provisions. The City must review current state statute and amend the Ordinance accordingly.

- **City Response:** City Staff requests to meet and confer with HCD on the City's height limits. Unless the ADU violates setbacks, the height limitation will default to the height limitation established in the underlying zone. In every zoning district, the height limit is greater than 25 feet. Thus, the City's height limits are *more permissive* in many instances than those established in Government Code section (c)(2)(D). Nevertheless, City Staff will review some of the limitations in 17.103.01 recommend the Council adopt Planning Code amendments to be consistent with this section.

- **HCD Comment:** Tables 17.103.01 and 17.103.02 – *Parking* – The Ordinance sets out the conditions for which parking is not required with the creation of an ADU. However, it omits reference to Government Code section 65852.2, subdivision(d)(1)(C), which states that no parking may be required when "…the accessory dwelling unit is part of the proposed or existing primary residence or an accessory structure." This would also include all JADUs. The City must note the exception.

- **City Response:** City Staff will recommend that the Council adopt a Planning Code amendment noting the exception to the parking requirement(s) for ADUs that are part of the proposed or existing primary residence or an accessory structure. However, City Staff notes that Table 17.103.01 already states "none required" for JADUs. Thus, the Ordinance already notes the exception for JADUs.

- **HCD Comment:** Table 17.103.01 – *Owner Occupancy* – The Ordinance states "Owner must occupy the JADU or the primary residence." However, Government Code section 65852.22, subdivision (a)(2), states "Owner-occupancy shall not be required if the owner is another governmental agency, land trust, or housing organization." The City must note the exception.

- **City Response:** City Staff will recommend that Council adopt a Planning Code amendment noting the exception that "Owner-occupancy shall not be required if the owner is another governmental agency, land trust, or housing organization."

- **HCD Comment:** Table 17.103.02 – *Unit Mixture* – The Ordinance states that a Category 3 ADU "precludes creation of any other ADU." There are three ADU types governed by Category 3. First, it includes some units created pursuant to Government Code section 65852.2, subdivision (a) – namely, new-construction attached units. However, Government Code section 65852.2, subdivision (a), permits ministerial approval of a compliant ADU with an existing or proposed primary dwelling unit, either multifamily or single-family. Subsequent to this allowance in subdivision (a), subdivision (e) begins with "notwithstanding subdivisions (a) through (d), inclusive, a local agency shall ministerially approve an application for a building permit within a residential or mixed-used zone to create any of the following…" before listing the four categories of subdivision (e) units. Therefore, the prior existence of an attached new-construction Category 3 ADU cannot preclude the development of a Category 1 or Category 2 ADU.

Secondly, another ADU type governed by Category 3 is a converted unit created to the same dimensions as a "legally existing attached accessory structure" in multifamily structures. This conforms to Government Code section 65852.2, subdivision (e)(1)(C). The Ordinance must permit the combination of such a unit with other units built subject to Government Code section 65852.2, subdivision (e), as discussed in the finding *Unit Mixture* above. The City must note the exceptions.

- **City Response:** City Staff will recommend that Council adopt a Planning Code amendment that revises the table to remove the note to establish the allowable unit combination. The City notes that this appears to be a shift from a prior HCD interpretation, which the City relied upon in initially creating these tables. The fact that three ADUs (one conversion ADU, one JADU, and one detached ADU) may be approved per single-family lot or that a Category 3 ADU may be created **in addition to** subdivision (e) ADUs only further underscores the gravity of the threat of increased population density on narrow and circuitous roads in the S-9 Overlay Zone. In addition, the State law apparently does not require off-street parking for these ADUs under several circumstances, even though the S-9 Overlay area is severely underserved by public transit. This will have disastrous consequences for fire evacuation in the S-9 Overlay Zone, both in terms of number of people needing to evacuate and the vehicular congestion, both from anticipated on-street parking and vehicle delay on the already narrow and circuitous roadways.

- **HCD Comment:** Table 17.103.01, Note (5) – *Ingress* – The Ordinance states that an expansion of not more than 150 square feet (s.f.) may be permitted for the purposes of ingress if "…the ADU is no greater than eight-hundred (800) square feet." However, the allowance for expansion to accommodate ingress and egress may be for a unit that conforms to Government Code section 65852.2, subdivision (e)(1)(A)(i), which reads that the unit "…may include an expansion of not more than 150 square feet beyond the same physical dimensions as the existing accessory structure." (Emphasis added). Note that such expansions are not dependent on the size of the unit but are only permissible with an "existing accessory structure." Therefore, the City must remove this reference.

- **City Response:** City Staff will recommend that the Council adopt a Planning Code amendment removing reference to the square footage limitation for 150-square foot expansions for ingress and egress. However, City Staff will recommend that the Ordinance is clear that the expansion must not be more than 150 square feet beyond the same physical dimensions as the existing accessory structure.

- **HCD Comment:** Tables 17.103.01 and 17.103.02 – *Maximum Size* – The Ordinance states that converted One-Family units be "50% of floor area of primary residence or 850 s.f., whichever is greater, but shall not exceed 1,200 sf." It later states that detached ADUs with multifamily primary dwellings be no larger than "850 sf. for studio or one-bedroom; 1,000 sf. for 2 bedrooms or more." However, local design standards provided by the Ordinance pursuant to Government Code section 65852.2, subdivisions (a) through (d), may not preclude a unit built subject Government Code section 65852.2, subdivision (e), which includes all converted units. Therefore, the City must amend the tables to note that no size maximums apply to any converted unit or any detached unit with a multifamily primary dwelling.

- **City Response:** City Staff will recommend that the Council adopt a Planning Code amendment clarifying that no size maximums apply to any converted unit or any detached unit with a multifamily primary dwelling. However, as noted elsewhere in this Response Letter, the City seeks clarification as to how this is consistent with Government Code section 65852.2(a)(1)(D)(v), which permits the City to enact an ordinance wherein the ADU size limitation is 1,200 square feet. The City is also concerned that there may be circumstances where the existing or proposed structure is larger, or the same size as, the primary structure. In those cases, the ADU would be indistinguishable from the primary dwelling, which appears to be contrary to the intent of State law to have a structure that is truly "accessory" and subordinate to the primary structure, and may also affect the affordability level of the ADU. Again, the City believes HCD may be too broadly interpreting what they believe is a subdivision (e) preemption of every provision in subdivisions (a) through (d) when subdivision (e) is silent as to, for example, public safety or size limitation.

- **HCD Comment:** Tables 17.103.01 and 17.103.02 – *Front Setbacks* – The Ordinance requires, for One-Family Primary dwellings, front setbacks "established by the development standards of the underlying zoning district, except when lot conditions preclude creating one ADU of no more than 800 s.f. and no more than 16 feet in height…." A similar condition exists for multifamily buildings in table 17.103.02, though two ADUs are allowed in the exception for Category 1 and 2 ADUs and one ADU is allowed in the exception for Category 3. The issues with restrictive unit allowances have already been addressed. However, the absence of alternative siting may not be a prerequisite for allowing an ADU in the front setback. Government Code section 65852.2, subdivision (c)(2)(C), does not condition placement of an 800 square foot unit on no other sites being available. Therefore, the City must remove these sections.

- **City Response:** City Staff requests that we meet and confer regarding this HCD Comment. Government Code section 65852.2(c)(2)(C) states that the City shall not establish by ordinance "[a]ny . . . limits on front setbacks . . . for either attached or detached dwellings that **does not permit at least an 800 square foot accessory dwelling unit with four-foot side and rear yard setbacks to be constructed in compliance with all other local development standards**." (Emphasis added.) The City simply requires that the applicant establish they cannot place the ADU elsewhere on the lot to avoid a proliferation of ADUs that violate the front setback. Such requirement does not prevent at least an 800 square foot ADU with four-foot side and rear yard setbacks and is thus consistent with State law. This provision of State law simply wants to ensure that a property owner will receive approval for an ADU of at least 800 square feet with four-foot rear and side yard setbacks. The Ordinance ensures that the ADU applicant would receive such ADU. The City simply requires that the ADU's preferred location be behind or to the side of the primary structure instead of in the front setback. State law does not appear to prohibit such preference, but instead prevents the City prohibiting an ADU if the ADU can be placed in the front setback.

- **HCD Comment:** Tables 17.103.01 and 17.103.02 – *Lot Coverage, FAR and Open Space* – The Ordinance allows "One JADU and One ADU of no more than 800 s.f. that is no more than 16 feet in height with at least 4-foot setbacks." It also requires that, relative to FAR requirements for multifamily primary dwellings, "New ADUs must be consistent with the regulations contained in the underlying zoning district, except to establish one or two Category Two ADUs of no more than 800 sf." It requires that for multifamily primary dwellings, "required open space for existing units, as established by the underlying zoning district, must be maintained…" except to allow exempted units. It has already been noted that the City must ministerially permit ADUs subject to different sections of statute in combination with one another; likewise, the height limitation has been addressed. However, be further advised that lot coverage, FAR and Open space requirements may not preclude any unit subject to Government Code section 65852.2, subdivision (e), which includes all conversions, JADUs, new construction detached units up to 800 square feet with single-family primary dwellings, and up to two detached units with multifamily dwellings. The City must amend the Ordinance to comply with statute.

- **City Response:** City Staff will recommend that the Council adopt Planning Code amendments clarifying that development standards such as Lot Coverage, FAR and Open Space shall not preclude certain subdivision (e) ADUs. However, City Staff requests to meet and confer with HCD regarding the negative consequence this will have on existing tenants: specifically, that the reduction of Open Space on multifamily parcels will inevitably result in a reduction of an important tenant amenity (open space) in favor of a property owner creating an excessively large (and therefore less affordable) ADU (or two) on the property. This appears to be contrary to the intent of the State law to address the housing crisis through housing affordability. In fact, it will result in the reduction of tenant protections, and the construction of excessively large, and thereby less affordable, ADUs. As such, the absence of a square footage limitation on detached ADUs on multifamily properties appears to be nothing more than an oversight in State law, especially with the express size limitation of 1,200 square feet that is set forth in Government Code section 65852.2(a)(1)(D)(v). We understand subdivision (e) is "notwithstanding subdivision (a)," but subdivision (e) also does not expressly prevent the City from establishing a size limitation.

- **HCD Comment:** Table 17.103.02 (2) – *Nonhabitable Space Definition* – The Ordinance defines non-habitable space in multifamily primary dwellings: "Non-habitable or non- livable space does not include detached accessory structures, existing residential units, commercial space, community rooms, gyms, laundry rooms or any other finished spaces that are meant to be occupied by people and used communally." However, statute defines such space much more broadly in Government Code section 65852.2, subdivision (e)(1)(C): "…including, but not limited to, storage rooms, boiler rooms, passageways, attics, basements, or garages." There is no condition in statute to require that such spaces *not* be "any other finished spaces that are meant to be occupied by people". Defining it in this way is potentially restrictive and thus violates State statute. The City must remove the quoted language.

- **City Response:** City Staff request to meet and confer with HCD regarding this Comment. Admittedly, State law does include the broad language, "including, but not limited to," but also sets forth a class of spaces that are unfinished areas such as "storage rooms, boiler rooms, passageways, attics, basements, or garages." None of those areas listed would be construed as finished areas that are regularly used by tenants. In Oakland, tenant protection is a high priority, and is also another means of addressing the extreme housing crisis and lack of housing affordability. The City has an interest in ensuring that property owners do not attempt to manipulate State law to constructively evict tenants by removing their important tenant amenities, such as laundry rooms, gyms, and other finished room amenities. Since none of these finished room spaces are mentioned in the "class" of examples provided, City Staff believes that the intent of State law was to permit ADU development in the unfinished spaces of multi-family buildings. Otherwise, State law would have stated that conversion ADU are permitted "anywhere in the multifamily building that is not already livable or habitable space." Since the State law is not that broad, the legislature appears to have intended to limit it to a class of unfinished spaces. Finally, the City is concerned that an expansive use of this provision could also disincentivize affordable density bonus projects because the applicant can achieve added density through the 25% allowance after advertising a project with finished tenant amenities they simply intend to convert. As such, City Staff would like to discuss this further with HCD.

City Staff appreciates HCD's efforts to provide valuable feedback on the City's Ordinance. The City also looks forward to meeting and conferring with HCD staff as to issues where there are still questions or interpretive differences.

Following your direction in the HCD Letter, City Staff will contact Mike Van Gorder to schedule a meeting with Mr. Van Gorder and other HCD staff on these unresolved issues. During the meeting, City Staff will also be prepared to share updates on the legislative process to update the City's Ordinance and/or findings. In the meantime, if you have any questions, please contact me.

Sincerely,

William A.Gilchrist

William A. Gilchrist
Director, Planning and Building Department
City of Oakland

cc: Brian P. Mulry, Supervising Deputy City Attorney, Land Use

[List of Attachments on Following Page]

Shannon West
Housing Accountability Unit Chief

Attachments:

Attachment A: City of Oakland Zonehaven Model Evacuation of an Event Similar to the 1991 Oakland Firestorm Under Current Conditions

Attachment B: Excerpts from the Draft Oakland Hazard Mitigation Plan (2021-2026)

Attachment C: City of Oakland Wildfire Prevention Planning Report

Attachment D: Draft Oakland Vegetation Management Report

Attachment E: City Administrator Letter to Planning Director Bill Gilchrist

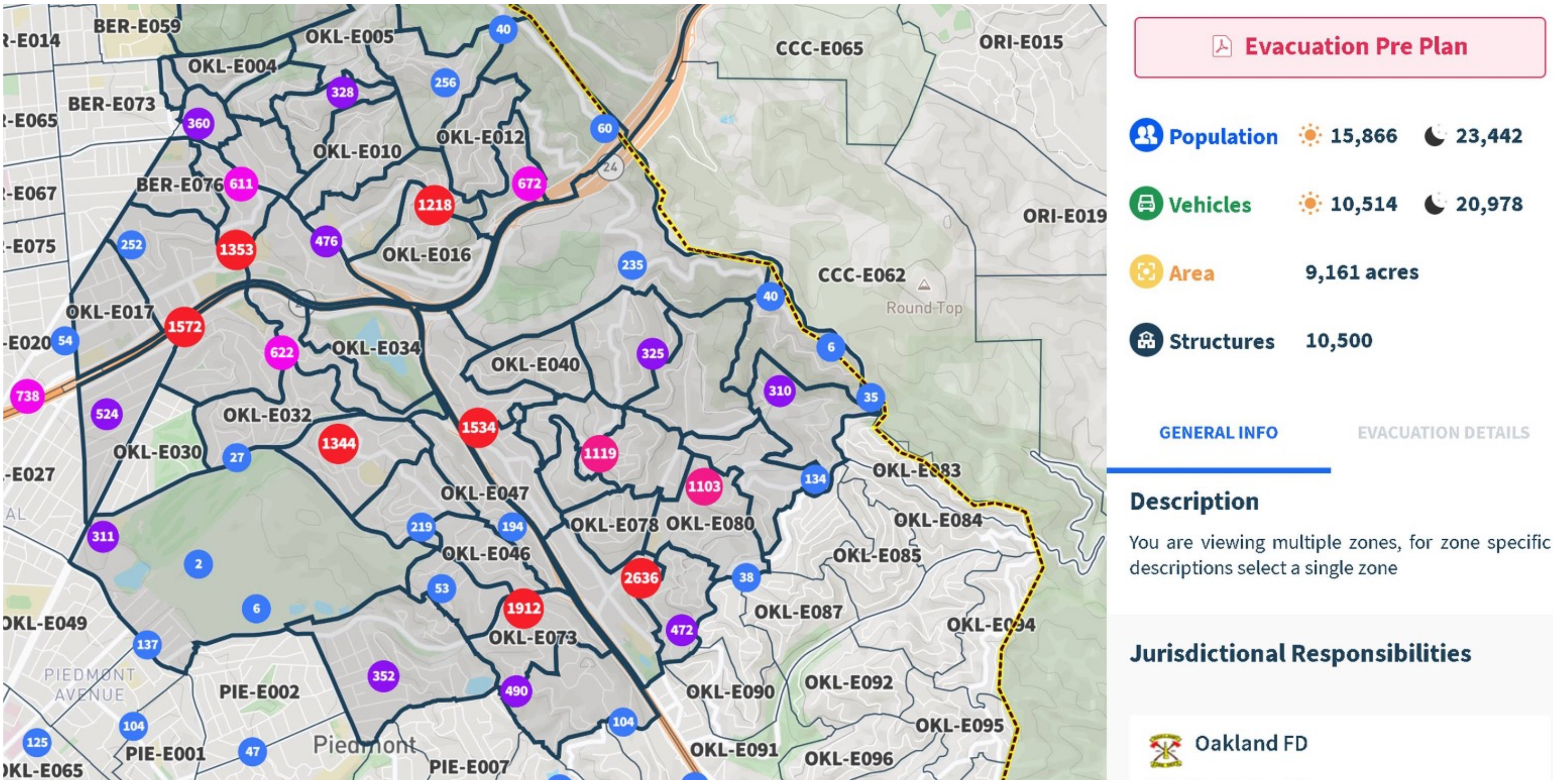
Attachment F: Oakland Fire Department Letter In Support of Restrictions for ADUs

Attachment G: UC Berkeley Study: *Developing Transportation Response Strategies for Wildfire Evacuations via an Empirically Supported Traffic Simulation of Berkeley, California*

ATTACHMENT D

ATTACHMENT A

Annotated Screenshot of Zonehaven Software Model of Oakland's 1991 Firestorm Under Current Roadway Conditions



Population ☀ 15,866 ☾ 23,442

Vehicles ☀ 10,514 ☾ 20,978

Area 9,161 acres

Structures 10,500

Description

You are viewing multiple zones, for zone specific descriptions select a single zone

Jurisdictional Responsibilities

Oakland FD

Alameda County Office of Emergency Services has utilized *Zonehaven*, a software application that allows fire agencies throughout Alameda County to analyze emergency scenarios and determine infrastructure demands, including demand on streets, during mass evacuations. The software tool is currently being tested for a full public rollout later this year and will be critical to assisting with the real-time notification and coordination needs of any community evacuation.

Please note: This screenshot is for illustrative purposes only. It does not provide a full picture of the evacuation scenario, and it does not show all available inputs and outputs. The application requires an interpretation by a trained specialist from Oakland Fire Department. This exhibit is in support of a live demonstration of the tool by the OFD Chief during City Planning Commission hearing on June 2nd, 2021.

The image from one of *Zonehaven* tools is modeling an emergency evacuation scenario similar in scale to the Oakland firestorm of 1991. According to a trained OFD specialist, the image shows that there is not enough time or capacity to clear key intersections along main routes during mass evacuations from areas of Oakland Hills outlined in black. The map outlines the areas affected by a wildfire. The multi-colored circles with numbers represent the number of vehicles trying to escape through a given intersection along evacuation routes during a hypothetical mass evacuation. The brighter the circle, the more significant the "choke point" at a given intersection. Blue circles represent the least challenging intersections while red circles represent the most challenging and dangerous intersections.

This choke point issue goes beyond individual road pavement widths. Even wide intersections can experience severe bottlenecks during mass evacuations. The bottleneck issue also affects larger areas near or far away from the intersections shown, **even in places where roads have sufficient pavement width**. *Zonehaven* demonstrates a situation where escaping vehicles cannot clear a stalled intersection and trapping people in their cars. This condition also prevents emergency vehicles from being able to get to the fire and people in need of emergency assistance.

Excerpts from Oakland Local Hazard Mitigation Plan 2021 – 2026 (Draft document):

Link to the full document: https://cao-94612.s3.amazonaws.com/documents/2021-04-30_OaklandHMP_AgencySubmittalDraft_2021-05-13-231111_rlny.pdf

15.1.1 Fire Hazard Severity Zones

The California Department of Forestry and Fire Protection (CAL FIRE) has modeled and mapped wildfire hazard zones using a computer model that designates moderate, high, or very high fire hazard severity zones (FHSZ). FHSZ ratings are derived from a combination of fire frequency (how often an area burns) and expected fire behavior under severe weather conditions. CAL FIRE's model derives fire frequency from 50 years of fire history data. Fire behavior is based on factors such as the following (CAL FIRE, 2013):

- **Fuel**—Fuel may include living and dead vegetation on the ground, along the surface as brush and small trees, and above the ground in tree canopies. Lighter fuels such as grasses, leaves and needles quickly expel moisture and burn rapidly, while heavier fuels such as tree branches, logs and trunks take longer to warm and ignite. Trees killed or defoliated by forest insects and diseases are more susceptible to wildfire.
- **Weather**—Relevant weather conditions include temperature, relative humidity, wind speed and direction, cloud cover, precipitation amount and duration, and the stability of the atmosphere. When the temperature is high, relative humidity is low, wind speed is increasing and coming from the east (offshore flow), and there has been little or no precipitation, so vegetation is dry, conditions are very favorable for extensive and severe wildfires. These conditions occur more frequently inland where temperatures are higher, and fog is less prevalent.
- **Terrain**—Topography includes slope and elevation. The topography of a region influences the amount and moisture of fuel; the impact of weather conditions such as temperature and wind; potential barriers to fire spread, such as highways and lakes; and elevation and slope of land forms (fire spreads more easily uphill than downhill).

The model also is based on frequency of fire weather, ignition patterns, and expected rate-of spread. It accounts for flying ember production, which is the principal driver of the wildfire hazard in densely developed areas. A related concern in built-out areas is the relative density of vegetative fuels that can serve as sites for new spot fires within the urban core and spread to adjacent structures. The model refines the zones to characterize fire exposure mechanisms that cause ignitions to structures. Significant land-use changes need to be accounted for through periodic model updates.

ATTACHMENT D ATTACHMENT B

15.2.2 Past Events

The most significant wildfire in recent history was the 1991 Tunnel Fire (aka Oakland Hills Fire and East Bay Hills Fire; see Figure 15-1). The fire started October 19 and was brought under control on October 23. It burned 1,520 acres, destroyed more than 3,200 structures, and had 25 confirmed deaths. Northeasterly winds, known as Diablo Winds, that periodically occur in the fall contributed to the growth of the grass fire eventually generating its own wind, now known as a firestorm.

15.2.3 Location

In Alameda County, wildfire risk is primarily in the WUI areas with moderate, high, or very high fire threat risk. These are high-density areas in the mountainous and hillside areas of eastern Oakland and Berkeley, central Union City, and some portions of the southeastern corner of Alameda County (CAL FIRE, 2021). CAL FIRE’s FRAP website includes maps of the communities most at risk for wildfire that are within 1.5 miles of a high or very high wildfire threat on federal or non-federal lands.

15.2.6 Warning Time

If a fire does break out and spread rapidly, residents may need to evacuate within days or hours. A fire’s peak burning period generally is between 1 p.m. and 6 p.m. Once a fire has started, fire alerting is reasonably rapid in most cases. The rapid spread of cellular and two-way radio communications in recent years has further contributed to a significant improvement in warning time.

15.7 Issues

- The number of annual wildfire events within Alameda County has held steady over the last 10 years at about 40 fires per year. Any of these 40 fires could have the potential to escalate, especially in the Oakland Hills as was seen in 1991.
- Over 13 percent of the planning area’s population lives in either high or very-high wildfire severity zones.
- Much of the planning area’s building stock is of wood-frame construction built before 2008 when California building codes began requiring minimum standards for buildings in fire hazard severity zones. Large clusters of structures are wood-frame structures in high and very high severity zones.

- An estimated 35 percent of the critical facilities in the planning area are located in wildfire risk areas. A large number of the facilities are believed to be wood-frame structures. These facilities could have a significant amount of functional downtime after a wildfire. This creates not only a need for mitigation but also a need for continuity of operations planning to develop procedures for providing services without access to critical facilities.
- **There are vulnerable and isolated populations in areas of high and very high risk for wildfire.**
- Public education and outreach to people living in the fire hazard zones should include information about and assistance with mitigation activities such as defensible space, and advance identification of evacuation routes and safe zones.
- Wildfires could cause landslides as a secondary natural hazard.
- Analyses based on the degree of wildfire risk should be updated to match new calculations.
- Regional consistency, application and enforcement of higher building code standards such as residential sprinkler requirements and prohibitive combustible roof standards.
- Fire departments require reliable water supply in high-risk wildfire areas.
- **The Oakland WUI is fully built out, and evacuation in the event of a widespread fire can be restricted by a dense population attempting to leave the area in many vehicles at the same time. This can be compounded by narrow urban streets with parked cars creating barriers to evacuation. Planners and traffic engineers must look at the entire evacuation route. Most roads leading out of the City's hills are one lane in each direction. This could inform mitigation strategies that address road infrastructure projects in the WUI.**

ATTACHMENT D

DISTRIBUTION DATE: ________________

CITY OF OAKLAND

MEMORANDUM

TO:	HONORABLE MAYOR & CITY COUNCIL	**FROM:**	Joe DeVries Director, Interdepartmental Operations
SUBJECT:	Wildfire Prevention Planning	**DATE:**	September 14, 2020

City Administrator Approval Date:

INFORMATION

On November 19, 2019, the City Council adopted Resolution No. 87940 C.M.S., declaring Wildfire Prevention a top priority for the City of Oakland and requesting the City Administrator to present a comprehensive report to the Public Safety Committee (PSC) that addresses Oakland's Wildfire Prevention Strategies within 180 days. The specific guidance in the resolution was as follow:

Submit a Report That Addresses: 1) How City Departments Will Address Wildfire Prevention In Their Planning, Programs And Projects For Oakland's Wildland Urban Interface (WUI), Including The Extent To Which The Strategies Will Involve Multi-Disciplinary And Multi-Agency Teams In The Development Of Pre-Fire Plans, 2) What Wildfire Prevention Plans Will Include Such As Home Hardening, Evacuation And Other Wildfire Prevention Strategies For Both Private And Public Properties, And Public Communication Strategies, Before, During And After A Wildfire Event, And 3) The Extent To Which Wildfire Prevention Will Be Addressed In The Next Updates To The City's General Plan, Safety, Open Space, Hazard Mitigation Plans And Other Similar Plans.

BACKGROUND / LEGISLATIVE HISTORY

Wildfires are a natural part of California's landscape and the potential risk of wildfires impacting communities in, and adjacent to, forested areas is at an all-time high. In the last few years, California has experienced the deadliest and most destructive wildfires in its history. Oakland's history of wildfires is no secret in California, the Oakland firestorm of 1991 was one of the largest urban wildfires. The fire started on the border of Oakland and spread throughout the Oakland and Berkeley hills. Ultimately 25 lives were lost, 150 people were injured, over fifteen hundred acres of land were burned, and thousands of homes were destroyed. The high winds, steep terrain, and heavy fuel load made fighting this historic blaze a major challenge. The economic loss from the fire was estimated at $1.5 billion.

The City Council adopted Resolution No. 87940 C.M.S. in response to the increased concerns of the past few fire seasons. As a response to this concern, the City established a Wildfire Prevention Working Group that meets regularly to both address short term needs and to continue the various long-term strategy planning and implementation. The Wildfire Prevention Working Group consists of the following Departments: Oakland Fire Department (OFD), Oakland Public Works (OPW), Department of Transportation (OakDOT), Bureau of Planning and Building (P&B), Oakland Police Department (OPD), and the City Administrator's Office as convener. Additionally, City Council staff serving constituents in the High Fire Hazard Zones in the hill areas were invited to attend.

This report is organized to be responsive to the three subject areas posed in the resolution and stated above. It also highlights some short-term actions that have been taken recently to reduce the risk of wildfire in Oakland. These include traffic control and parking restrictions in high fire danger areas, vegetation removal efforts, and coordination with outside agencies and jurisdictions.

1) How City Departments Will Address Wildfire Prevention In Their Planning, Programs And Projects For Oakland's Wildland Urban Interface (WUI), Including The Extent To Which The Strategies Will Involve Multi-Disciplinary And Multi-Agency Teams In The Development Of Pre-Fire Plans

Oakland's Vegetation Management Plan

The most critical piece to the City's planning efforts at reducing the risk of wildfire is the Oakland Vegetation Management Plan (the Plan). The Plan is complete and OFD is preparing the Environmental Impact Report (EIR) on it to comply with the California Environmental Quality Act (CEQA). The Plan outlines a framework for managing fuel loads and vegetation on City-owned properties and along roadways in the City's wildland urban interface (WUI) areas to reduce the likelihood of a catastrophic wildfire, such as the 1991 Oakland Hills Fire, and to reduce the likelihood and scope of injury and property damage if such a fire occurs.

The Planning Area encompasses approximately 1,925 acres, and 308 miles along roadsides, including City surface and arterial streets, State Routes 13 and 24, and Interstate 580.
Staff provided an update to the Oakland City Council Public Safety Committee on December 3, 2019 and to the full Council on December 10, 2020 on the Plan.

Below is a link to the Agenda Report:
https://oakland.legistar.com/LegislationDetail.aspx?ID=4249996&GUID=62C57E61-1BD7-4D2D-A104-4BC20395DD2E&Options=&Search=.

The timeline for the Plan is as follows:
- Horizon/Dudek provided the Administrative Draft Environmental Impact Report (EIR) to City (August 2020);
- City reviewing Administrative EIR draft (Fall 2020);
- City publishes the Public Draft EIR (Fall 2020);

ATTACHMENT C

ATTACHMENT D

- Forty-five-day Comment period on Draft EIR commences (Fall 2020);
- City presents the Draft EIR to Planning Commission and receives public comment (Fall 2020);
- Horizon/Dudek prepares final EIR including responses to comments received (Fall/Winter 2020);
- City revises Draft EIR and Revised Draft Plan (Fall/Winter 2020);
- City presents the Plan and EIR to the Planning Commission (Winter 2020);
- Certification of Plan and EIR by the City's Planning Commission (Spring 2021);
- City Council Committee meetings (Public Safety and Public Works) (Spring 2021);
- City Council Hearings (expected Spring 2021);
- Adoption of the Plan by the City Council (Spring 2021); and
- File Notice of Determination filed with Alameda County Clerk Recorders Office and the California Environmental Quality Act (CEQA) State Clearinghouse (Spring 2021; must be posted for 30 days).

Financing of Plan Implementation [Source: Council Informational Memo, December 10, 2019, https://oakland.legistar.com/LegislationDetail.aspx?ID=4249996&GUID=62C57E61-1BD7-4D2D-A104-4BC20395DD2E&Options=&Search=]

Members of the public have expressed interest in how the implementation of the Plan will be financed. The Plan itself does not provide any recommendations regarding sources of funding to implement the Plan. Those decisions are made by the City Council during the City's Biennial Budget and Mid-Cycle Budget processes. However, the Plan does include preliminary estimates for the costs of actions contained in the Plan. Please refer to Section 12.5, Implementation Costs, on page 236 of the Plan and Appendix H of the Plan for more information. It should be noted that these costs will fluctuate over time, based upon a number of different factors; however, these estimates will provide baseline information that can help inform the City's budget discussions and any planning for any future assessment.

Until 2017, OFD was able to use proceeds from the Wildfire Prevention Assessment District (WPAD) to pay for vegetation management activities. In order to provide funding for vegetation management and mitigation programs/services specific to the WPAD, a ten (10) year parcel assessment on properties located within the designated WPAD was approved by voters in 2004. The assessment resulted in an annual WPAD budget with expenditure line items recommended and approved by the WPAD Citizen Advisory Board in conjunction with the OFD, to be used for vegetation management and mitigation programs/services. The WPAD provided the City with an average of one million seven hundred thousand dollars ($1,700,000) in revenues that could be used for wildfire hazard reduction services in the Oakland Hills. These services were described in the 2013-14 Engineer's Report for the Assessment District as: Goat Grazing; Property Owner Chipping Program; Vegetation Management Program; Roving Fire Patrol Program; Support Services for Inspection Programs; and Public Outreach.

In November 2013, a ballot measure to continue the property tax assessment and activities supported by the WPAD was forward to voters; however, the WPAD failed to earn the affirmative vote of more than 2/3 of the electorate in the District. As a result, the parcel tax expired in 2014 and the remaining fund balance was completely expended by June 30, 2017. OFD Vegetation Management currently relies on funding appropriated from the General Purpose Fund (Fund 1010) by City Council in the City's Adopted Policy Budget for Fiscal Year (FY) 2019-2021. For FY 2019-20 and 2020-21, OFD Vegetation Management was appropriated two million nine hundred and twenty-six thousand, five hundred and thirty dollars ($2,926,530) and two million forty-six thousand, two hundred and twelve dollars ($2,046,212), respectively. These amounts include for each FY one-time funding of one hundred thousand ($100,000) for the Plan and one million one hundred thousand dollars ($1,100,000) in lieu of a renewed Wildfire Prevention District. An additional nine hundred thousand dollars ($900,000) in one-time funding was also provided in FY 2019-20 (Year 1 of the biennial budget) with the intention of accelerating vegetation management operations to prepare for FY 2020-21 (Year 2) wildfire season.

The Creation of a Multi-Disciplinary and Multi-Agency Approach to Wildfire Prevention

Until the launch of the Wildfire Prevention Working Group, City departments were not entirely coordinated on the topic of wildfire prevention or large-scale emergency preparedness. The simple act of launching the Working Group focused on this single topic expanded the lens of City departments to see how each of their respective functions play an important role in how the City prevents, prepares for, and responds to wildfires.

During regular meetings, which occur twice monthly, working group members representing several departments have an opportunity to explore and learn about the range of strategies the City of Oakland uses to proactively mitigate wildfire risk, like the Fire Prevention Bureau's vegetation management program. It also provides a chance for staff to ask and respond to questions from other City staff, elected officials, community organizations and residents on issues such as how we approach parking restrictions in the hills, best practices for home hardening, evacuation planning, and coordination with outside agencies such as PG&E or jurisdictions like East Bay Regional Park system.

The following sections of this report will break down the Multi-Disciplinary and Multi-Agency Strategies the City is applying in order to ensure it is strategic in its efforts to prevent the ignition, spread, growth and intensity of a wildfire in our city.

The Fire Prevention Bureau: Vegetation Management and Annual Inspections

The Fire Prevention Bureau's Vegetation Management Unit, a division of the Oakland Fire Department, has made outstanding progress in 2020 with regards to Wildfire Planning and Prevention. Beginning in March of 2020, the Vegetation Management Unit initiated the release of abatement contracts for roadside clearances and clearing of City owned parcels throughout Oakland's designated Very High Fire Severity Zone. To date, 33 contracts have been released for competitive bid, and 19 of those abatement contracts have been completed, 4 are in progress and 10 are awaiting the encumberment of funding to begin. The Vegetation Management Unit anticipates releasing another 10 contracts before the end of the fiscal year. For the first time since

2014, the Vegetation Management Unit has been fully funded (an additional $1,000,000.00 was added into the Vegetation Management Unit 19/20 fiscal budget in October of 2019) with regards to its abatement account.

Major egress route roadways within the Oakland Hills were cut and cleared of hazardous roadside vegetation prior to the July 4th holiday, increasing the community's safety and decreasing the fire threat. Additionally, through the contracted goat grazing program with Ecosystems' Concepts Inc., goats were deployed in April 2020 to the Grizzly Peak Open Space, North Oakland Sports Field & Tunnel Road City Parcels and in June to the Kings Estates Open Space and Joaquin Miller Park with Knowland Park and Sheffield Village completed in July 2020.

The Vegetation Management Unit is on track to abate over two thirds of the City owned undeveloped parcels and parklands prior peak fire weather conditions of late August, September and October of 2020. The Acting Vegetation Management Supervisor and his team of Fire Inspectors are actively inspecting privately owned vacant lot parcels for fire code compliance and guiding the annual Residential Inspections conducted by the Engine Company Firefighters at 11 Oakland Hills Fire Stations that began in June 2020. While facing increased fire probability due to the weather patterns of the spring of 2020, the OFD as a team has made significant progress in wildfire mitigation this fire season.

Fire Prevention Inspections

In addition to the City's current efforts to manage wildfire risk on its property, the City also adopts amendments to the California Fire Codes which requires owners of both public and private properties in the High and Very High Fire Hazard Severity Zones (H/VHFHSZ) to take additional safety measures to reduce the likelihood of wildfires and to prevent their spread. Examples of these safety measures includes installing sprinklers on new structures or those undergoing a major remodel; and maintaining defensible space around a building. Defensible space is defined as an area around a building where vegetation, trash and debris, and other types of flammable fuels have been treated, cleared, or reduced to slow the spread of fire both to and from the building. Low-cost measures like maintaining defensible space or screening attic vents can help protect Oakland's housing stock and increase fire safety community-wide.

The Oakland Fire Code not only establishes building and property maintenance standards, but also provides for their enforcement. The Vegetation Management Unit coordinates the City's vegetation inspection efforts. Each year, property owners in the Oakland hills receive an annual inspection by OFD. Although properties are inspected once a year, they are expected to maintain defensible space around their property year-round.

Recent Inspection System Upgrade

OFD transitioned to a new inspection and permitting database called Accela which has been used by the Planning and Building Department for several years. This transition involved moving from paper/pen documentation to compiling inspection data with electronic devices (iPads and iPhones). An essential piece of this conversion includes the documentation of inspections with photo images collected with electronic devices. By capturing images of the property/site at the time of inspection, OFD can document Compliance or Non-Compliance, ensure inspections are completed in accordance to inspection requirements, respond to complaints, use photos for inspection training and provide transparent inspection data to registered property owners and their authorized agents.

Digital images of the inspection site and status at the time of the inspection allows OFD to compile an accurate account of the inspection details. This information can then be reviewed to ensure quality inspection and training; and give a transparent account of the inspection. In combination with the use of the citizen facing portal called ACA (Accela Citizen Access), a registered user can access the record details in the Accela database. This project is a complete renovation of the former manual inspection system to the use of new software and hardware to document inspection details with real time data.

The technology provides clearer documentation of the inspections completed. It also allows inspection documentation to take place much more quickly and be linked to other vital information about the property through the Accela system.

OFD began using the technology in May of 2018 to process vegetation inspections in the Wildfire Protection areas of Oakland. These inspections are completed by firefighters and vegetation inspectors on an annual basis. The technology was deployed out of the Fire Marshal's office with joint staff from the Fire Prevention Bureau and OFD command staff. The technology is used daily by the engine company staff and inspectors from the Fire Prevention Bureau to document scheduled inspections and complaints.

OFD is in the process of converting all of its fire inspections to the Accela system which will mean that any code, commercial, or other type of inspection will be tracked and stored in this system. This will create efficiencies that will improve fire safety citywide by allowing for more inspections to occur on an annual basis and will help identify problem properties where an elevated fire hazard may exist.

Additional Interdepartmental Coordination

Oakland Public Works

OPW – Keep Oakland Clean and Beautiful
Keep Oakland Clean and Beautiful (KOCB), a unit in OPW, clears public right of ways and hardscape medians below I-580. KOCB has a seven-person crew for this purpose. While the OFD is primarily responsible for vegetation management in the former Wildfire Prevention Assessment District areas, there are some instances where OPW provides service. For example, if there is vegetation in the right-of-way that is obstructing the view of a regulatory sign or traffic, OPW will attempt to resolve those issues. Previously, KOCB was also able to partner with non-profit organizations such as the Center for Employment Opportunities and the Alameda County Sherriff's Work Alternative Program to assist with roadside clearance.

OPW – Parks and Tree Services Division

The Parks and Tree Services Division of OPW oversees tree removal activities for the City as well as landscaping on improved City of Oakland properties, such as Woodminster Amphitheater, Joaquin Miller Park, Leona Lodge, Sequoia Lodge, Montclair Golf Course, etc. On improved parcels, brush is cleared a distance of at least fifteen (15) feet from buildings and structures. The Division also maintains landscaped medians throughout the City. Although the work was not done specifically as a wildfire prevention project, OPW did contract for the removal of ninety-five (95) dead and hazardous trees along Skyline Boulevard in 2019-20. As a result of budget reductions that occurred, OPW does not maintain City owned open space, nor does it prune or maintain trees for the purpose of wildfire prevention.

The Planning and Building Department

The Strategic Planning Division within the Planning and Building Department is addressing wildfire prevention strategies in several different areas in coordination with multiple departments and outside agencies. The department participates in the Working Group and their contribution to those efforts are covered below in section 3.

Department of Transportation

Fire Safe Streets Program (2015- Present)
Traffic Engineering Staff partners with OFD to determine ways to reduce the time it takes for OFD to arrive to the scene of emergencies. Every minute of a medical call, fire or other emergency, is critical to preserve lives and property. Cities and counties often use emergency response time as an evaluation measure. Further, responders require physical space in order to deploy their equipment at the scene, space which may be constrained by street design.

Poorly designed or inadequate infrastructure can hamper fire-suppression efforts and put residents and firefighters at risk. Reducing the risk of wildfire damage and destruction may require the City to implement measures beyond those involving an individual building or parcel. It is also essential to enhance mitigation measures at the neighborhood and community levels, which will effectively expand the zone of protection beyond an individual parcel or building.

In 2015, the team began evaluating traffic and life safety issues regarding emergency vehicle access and evacuation routes in the Oakland hills and what is commonly referred to as the Very High Fire Severity Zone.

The conversations stemmed from incidents where there was a delayed emergency response, and ongoing questions and concerns that were raised by residents about evacuation routes in the hills due to parked cars blocking the roadway.

The pilot program was launched, whereby twenty-one (21) streets were successfully surveyed and designated as “no parking." The program allowed the City to proactively restrict parking on narrow streets to test effectiveness and public reception. The target area for the pilot was neighborhoods north of Highway 13 between the Contra Costa/Berkeley border (to the west) and Keller Avenue (to the east). Community feedback about the program was very positive overall.

In 2019, the program transitioned from a pilot program to full implementation with the aim of providing safe passages throughout the designated Very High Fire Hazard Severity Zone (a state designated fire hazard zone) in Oakland.

The street segments below were identified by the OFD as locations where on-street parking has consistently obstructed emergency-vehicle access. For that reason, “No Parking Anytime” signs and, in some cases, red paint has been installed/refreshed on some or all of these roads:

Alvarado Road, Bristol Drive, Brunell Drive, Chelsea Drive, Dwight Way, Dwight Place, Gravatt Drive, Stonewall Road, Vicente Road, Vicente Place, Westview Drive, Florence Terrace, Westover Drive, Charring Cross Road, Capricorn Avenue, Norfolk Road, Ocean View Drive, and Heather Ridge.

Hazardous street conditions are brought to the attention of the City in the following ways:

- Correspondence from resident to City staff or Council member.
- Social media posts or comments.
- Community meetings.
- News Inquiries (typically initiated by community interest).
- Letters from community organizations.
- Reports from OFD crews following incidents.
- Calls to Oak311 and Parking Enforcement Dispatch

Streets are then surveyed, and some are identified as a roadway with limited emergency vehicle access. Streets are evaluated for sufficient width and space to allow safe passage and room to deploy equipment and personnel. Streets with limited access create significant challenges in providing emergency response for fire apparatus and ambulances year-round. Additionally, these streets may be the only option for escape during an escalating wildfire event or large-scale disaster. Unfortunately, OFD experienced this reality of vehicles not being able to navigate a road safely while evacuating and delaying emergency responders during the 1991 Firestorm, and other communities throughout California have experienced this more recently. Therefore, the following criteria are used in evaluating streets, and the determination of whether parking restrictions are necessary are specific to each road:

- Roads should be wide enough to allow evacuation and emergency vehicles simultaneous access. As a rule, the minimum width is 20 feet.
- However, street width is not the only determining factor used as most streets in the hills do not have consistent widths.
- Horizontal curves also require a wider clearance for vehicular passage and shoulder conditions, such as the presence of vegetation, walls, and other structures that affect how much a parked car would encroach onto the street, also contribute to the decision.

- Firefighters need room to deploy equipment and personnel. They also need to keep firefighters and equipment out of the collapse zone of structures. When working at the scene of an incident, fire departments usually need to accomplish some or all the following tasks:
    - Open cab doors so that firefighters can exit the apparatus
    - Retrieve equipment from compartments on the side of vehicles
    - Retrieve ground ladders from the vehicle
    - Connect fire hoses to pumps on the fire engine
    - Move equipment and vehicles around or beside the first fire vehicle to arrive at the scene
    - Keep firefighters and equipment at a safe distance from a structure or landscape collapse zone, if possible
    - When using an aerial ladder, OFD deploys stabilizers (a.k.a. outriggers) to prevent the ladder truck from tipping over when the ladder is extended to the side of the vehicle.
- The space that emergency responders need to be able to accomplish these tasks can vary considerably, depending on the kind of fire apparatus and other emergency response equipment chosen by a department, the type of incident, and the design of the neighborhood's streets, building design and street network.

Heather Ridge Way Example

Between 2018-19, residents on Heather Ridge Way continuously expressed concerns about emergency services being able to access their homes and if needed their ability to escape during a wildfire.

In 2019, Heather Ridge was evaluated several times by both OakDOT and OFD, and it was determined that the entire street met the requirements for restricted parking/emergency access. This evaluation consisted of measuring the entire street at different locations to determine where it fit into the Oakland Municipal Code (OMC).

The OFD and OakDOT staff met on site in May 2019 and drove a fire engine down the street (after measuring) to see if any areas could be used for "on street" parking and it was determined that was not practical and/or safe. All parties who worked on the project were dedicated to trying to accommodate the needs of the entire Heather Ridge community while also finding solutions to address the restricted ingress and egress issues.

Fire and OakDOT staff met in person multiple times with residents on the Heather Ridge. A community meeting was convened by Councilmember Sheng Thao's office with neighbors and staff. OFD sent three letters to the neighbors to residents impacted by the issue and participated in several local media interviews highlighting the importance of creating safe access routes.

Ultimately, it was determined that a large portion of the street had to be designated "No Parking" in accordance with the OMC and to ensure preservation of life and property.

Enforcement
OakDOT's Parking Enforcement Unit has supported these efforts the past several years in many ways, including attending staff and community meetings, promoting its dispatch service (available Monday through Friday, 8:30am to 5:00pm by calling 311 or 510.238.3099), and conducting special enforcement campaigns along the network of streets in Phase 1, 2 and 3. In addition to regular patrols, the Parking Enforcement unit now deploys technicians to the hills whenever there is a red flag warning. This standard procedure was implemented in mid-August with the City's first red flag warning of the year, resulting in the issuance of two citations along the approximately 35 street segments targeted. A second red flag warning campaign produced similar results, indicating fairly good compliance with the new parking regulations.

Recent Efforts to address immediate hazards on Grizzly Peak

When the Wildfire Prevention Working Group first came together in the spring, an immediate concern about Grizzly Peak Blvd was brought to the forefront. Large gatherings in the evenings, especially on weekends, were creating many hazards, especially with increased numbers of illegal fireworks being discharged leading up to the 4th of July Holiday. OFD tracked 6 wildfires on Grizzly Peak in a short 6-week period, the majority of which were caused by fireworks. Additionally, as people gather late into the evening and consume alcohol, traffic accidents are especially dangerous along this winding stretch of roadway and there have been incidents of violence/shootings occurring at the turn-outs. The majority of this problematic behavior is occurring in the evening. There are nine separate turn-outs where this activity occurs and those locations are all accessed by the City of Oakland roadway but the underlying turn-outs are under the jurisdiction of UC Berkeley, the City of Berkeley, and East Bay Regional Park District.

The Wildfire Prevention Working Group evaluated different measures to mitigate these issues in the short and long term. On July 4th, the City closed Grizzly Peak Blvd. to all through traffic (except pedestrians and bicyclists) and successfully avoided any fires that day. This plan was supported with freeway signage by Caltrans and all the adjacent jurisdictions supported the effort as well.

The group evaluated three options as a long-term approach:

1. Closing these turn-outs 24/7 during the fire season using some form of traffic barriers that could be removed when the fire season ends. This could entail using K-rails in the short term and then engineering removable barriers in future years. OakDOT provided cost estimates to use barriers to close all the turn-outs during this fire season and the cost is very prohibitive, ranging from $300,000 to $500,000. There is the potential that people would still stop to observe the panoramic views of the Bay Area and block a travel lane which would create an additional hazard. Also, the loss of those scenic locations for people to enjoy the views during the day was a consideration that many neighbors have cited as a reason to keep them open.
2. Closing Grizzly Peak completely in the evenings to through traffic during the fire season. A daily closure at the main entry points would require a smaller investment in physical barriers but would require staffing to close the gates each night, patrol the entire stretch to

allow people to leave (so they are not locked in), and then reopening in the morning. This poses too many logistical issues and a potential new safety issue for some neighborhoods that might use Grizzly Peak as an evacuation route (it is an identified evacuation route for the El Toyonal neighborhood of Orinda).

3. Prohibiting Stopping at all turnouts between 9pm and 6am and making them tow away zones on Red Flag Days.

The Wildfire Prevention Working Group selected option 3, and signs were installed on the week of August 29th. This measured approach gives law enforcement the proper signage to enforce the restriction through warnings and citations. The other jurisdictions that share responsibility can also issue citations, and the Wildfire Prevention Working Group can track the effectiveness this year and evaluate if more permanent barriers need to be installed or if this is sufficient. Also, this option allows for responsible persons to enjoy the view up until sundown while keeping the area off limits when the greatest potential hazards can occur.

The group is also evaluating locations on Skyline Blvd. in Council Districts 4 and 7 for a similar intervention due to large gatherings where fire hazards are high. Because the Wildfire Prevention Working Group meets on a regular basis with staff from all key departments, it has the ability to respond to emerging concerns quickly. The recent work on Grizzly Peak and recent efforts on Red Flag days are an example of that coordination.

Oakland Police Department

OPD has fully embraced the importance of Wildfire Safety and its impact on the Oakland Community. As a participant in the Wildfire Prevention Working Group, OPD will employ the following strategies to deter dangerous activity linked to wildfires:

- Police Area 2's Community Resource Officers opened a community policing project with community organizers, stakeholders, and City partners to address short-term and long-term improvements to Grizzly Peak public safety fire dangers.
- The OPD Public Information Officer (in conjunction with City and OFD media teams) will assist with public outreach and education regarding the importance of fire safety and the dangers of firework and unlawful activity related to fire danger in the City of Oakland.
- OPD will maintain the ability to monitor a Fireworks Tip—Line for use during high-risk seasons or dates; the line will have the ability to accept anonymous information regarding fireworks.
- Community Resource Officers will run educational/enforcement operations to address illegal activity in the "Very High Fire Severity Zone(s)" such as Grizzly Peak
- OPD will be the lead agency regarding the multi-jurisdictional annual shut down of the Grizzly Peak area during the July 4th (Independence Day) holiday.
- Neighborhood Services Coordinators will continue to work closely with community groups to identify evacuation routes, problematic locations and other resources available

- When resources, personnel and priorities permit, high fire danger areas will be patrolled by patrol officers and community resource officers to mitigate fire danger and other public safety issues that potentially aggravate public safety fire danger.

Outside Agencies/Partnerships

The City's partners in Wildfire Fire Prevention include the East Bay Regional Parks District, Moraga – Orinda Fire Department, East Bay Municipal Utilities District (EBMUD), CALTRANS, Lawrence Berkeley National Laboratory, U.C. Berkeley and PG&E. Through cooperative communication, our partners have completed numerous vegetation management projects throughout their respective lands within or adjacent to the City of Oakland that benefit our residents through the reduction of roadside fuels, thinning of invasive eucalyptus trees and goat grazing.

The East Bay Regional Parks District Fuels Management Crew has already completed brush removal in Tilden Park along Grizzly Peak and in Redwood Regional Park along Skyline Blvd. The Moraga – Orinda Fire Department recently completed controlled burns (June 2020) in both Moraga and Orinda (just 2.5 miles east of Oakland residential homes).

EBMUD conducted an invasive tree thinning project on watershed lands east of Grizzly Peak Blvd and south of Tilden Park that reduces canopy fire transfer along the wind-swept ridgeline to the northeast of Claremont Canyon area homes.

CALTRANS continues to abate the highway roadside vegetation along Highway 13 and Highway 580 with guidance from the OFD's Vegetation Management Unit.

Lawrence Berkeley National Laboratory has deployed goats which are actively grazing on their parcels below the Panoramic Way homes of Oakland.

U.C. Berkeley has completed extensive fuels reduction north of Claremont Canyon including invasive tree removal on its properties below Grizzly Peak Blvd and along Claremont Avenue.

PG&E created a fuel break from Highway 13 at Highway 24 east adjacent to Pali Court and through the canyon and ridgeline south of the North Oakland Sports Field to Broadway Terrace at Skyline Blvd. to protect its high voltage transmission lines and provide a buffer to the homes of upper Broadway Terrace.

This work by PG&E was completed with input from Oakland's Fire Prevention Bureau and its Vegetation Management Unit through monthly meetings provided by the Hills Emergency Forum, Diablo Fire Safe Council of Alameda and Contra Costa Counties and the OPW/ CALTRANS bi-monthly meeting.

The City's efforts continue to mitigate hazardous vegetation wherever present within the Oakland Hills. The City is fortunate to have built proactive relationships with our partnering agencies who recognize that these actions are necessary to protect the City's infrastructure, preserve life and property and enable the City to prosper without catastrophic loss due to wildfire.

Overall, the City's initiatives in this regard are working. The declared fire season of 2019 lasted 203 days in Oakland from May 13, 2019 to December 2, 2019. During that time, Oakland Fire responded to 11 wildland fire events in the Oakland Hills. No structures or lives were lost. That's a 94.58 % fire free success rate due to the fuels abatement project's work, reducing the probability of ignitions and most importantly, providing Firefighters time to respond and arrive on scene BEFORE an ignition event increases in size. Additionally, regular meetings with adjacent municipal Fire Departments, CALFIRE and other stake holder agencies provides familiarity with their Command Staff that transfers into efficient Fire Suppression Operations when fire events occur.

2) What Wildfire Prevention Plans Will Include Such As Home Hardening, Evacuation And Other Wildfire Prevention Strategies For Both Private And Public Properties, And Public Communication Strategies, Before, During And After A Wildfire Event

Home Hardening

In regard to Home Hardening, much of the work is captured in the inspections that are conducted on an annual basis and discussed above. Additionally, the Vegetation Management Plan covers this topic but most importantly is public education and that is covered below under the communications strategy section.

Evacuation Planning

The City of Oakland Emergency Management Services Division, OFD, OPD, along with other public safety agencies throughout Alameda County have identified the need to create a countywide evacuation plan. During the Summer of 2018, OFD, the Alameda County Fire Department, Berkeley Fire Department, Hayward Fire Department, CalFire, and the Alameda County Sheriff Office created the Alameda County Evacuation Task Force (XALETF). The core mission for the XALETF is to develop a countywide evacuation plan that will allow for the facilitation of an organized and integrated wildfire evacuation that isn't restricted to city or county boundaries.

In the fall of 2019, the multi-agency group initiated discussions with Zonehaven, a company that was creating technology to address the evacuation concerns of San Mateo County, Moraga/Orinda, and El Cerrito/Kensington. In early 2020, the XALETF agreed that the Alameda County Sheriff Office of Emergency Services would be the lead agency for coordinating the required funding utilizing grant allocations, facilitate sole sourcing, and negotiate a contractual agreement. The sole source process was completed early 2020, along with identifying a funding source to secure a five-year agreement with Zonehaven.

Unfortunately, in March 2020 progress on securing a contract was paused due to COVID 19. Nonetheless, as County Counsel and Zonehaven work to finalize the contract, Zonehaven is moving forward in creating the county evacuation zones and is working with the XALETF to develop a review and implementation plan. The XALETF anticipates having a preliminary platform in service by December 2020 assuming a contract can be executed in a timely manner and no additional unforeseen situations impede progress.

The Evacuation Management Platform

The Zonehaven Evacuation Management Platform is a zone-based application that makes it easy for OFD, law enforcement and the County Office of Emergency Services to collaborate, build, and maintain evacuation plans, train using evacuation simulations and scenarios, and notify agencies and the community in the event of a live emergency. The need for this cutting-edge technology has been demonstrated throughout California due to recent wildfires and in Oakland during the 1991 Tunnel Fire.

This evacuation platform will provide access to technology that will allow for the OFD, OPD, and Emergency Management Services Division to better understand community risk and assist with planning a safe and effective evacuation plan. Zonehaven is being developed as a regional evacuation application that will hopefully be utilized in all nine Bay Area counties eventually.

Zonehaven will be providing Oakland with a standardized evacuation plan that works on a common operating platform to facilitate essential cross boundary coordination. It will provide Oakland residents and first responders immediate evacuation warnings and orders when the situation dictates. The platform will empower OFD and OPD to make decisions on when to evacuate, which zones to evacuate, allow for monitoring critical evacuation traffic information in real-time, assist with creating pre-established traffic control points, pre-identify temporary refuge areas, and provides an interface to facilitate real-time wildfire modeling by Incident Commanders at the scene. Once operational, the vision is that a Zonehaven interface will be established that allows for connectivity with AC Alert, the Alameda County mass notification system that the City of Oakland utilizes (acalert.org). This concept of inter-connectivity is still in development between the two vendors. If successful, it will allow for evacuation information to be accelerated when needed. The Zone Haven Evacuation Management Platform will be used for all risk disaster mitigation that may include flooding, hazardous material leaks/spills, tsunami, and wildfires.

For more information about Zonehaven, go to the following links:
https://info.zonehaven.com/resources
https://www.youtube.com/watch?v=P3pXJ9NKEfc&feature=youtu.be

Communications Strategies Pre/During/Post Events

Timely, Accurate and Reliable information on the City website

With the onset of fire season and a range of current events happening concurrently, including the Covid-19 global pandemic, the City of Oakland's citywide public information team made up of staff from several departments is working aggressively to create a single location on the City website where residents and other interested parties can locate and learn about the best ways to prepare and respond to emergencies before, during and after they occur. The current webpage addressing wildfires can be found here: https://www.oaklandca.gov/resources/wildfire-event

Residents deserve to have access to a single reliable and accurate source where they can stay informed, and in the event of a major wildfire can get access to information at the following points:

- Before a fire: to prepare their household in advance
- When fire threatens: to stay ready in case they need to evacuate
- During a fire: for information on how and when to evacuate
- After a fire: for information on when they can return and what they're returning to.

The homepage on the City website will have a banner year round to direct people to guidance regarding emergencies, especially for wildfires preparedness and red flag warning days which are often triggered by anticipated stretches of of extreme heat, high winds and low humidity.

Helping Residents Stay Informed in the Moment

Another public education initiative that has been underway for the last year is an effort to increase the number of Oakland residents subscribed to AC Alert. Oakland residents need to be ready to evacuate in a wildfire with or without notice from public safety officials. Signing up to receive AC Alert emergency notifications via phone, text and email, is the most effective tool available to ensure we can reach community members if an evacuation is ordered.

Meanwhile, as the City promotes the benefits of AC Alert to its residents, it continues to seek out ways to enhance its own use of the tool and is working internally and with its county partners to formalize the type and scale of event that would prompt an AC Alert notification, and the most effective messaging to use during such events. The intent is to have the AC Alert notification from the City link back to a specific emergency page on the site, thus providing not just a notification but educational resources as well.

Emergency Preparedness Starts at Home

OFD's Emergency Management Division is in the midst of a major moment of growth, in terms of adding talented staffing capacity while seeking out opportunities for enhanced community partnerships. The City is looking forward to reinstituting a community preparedness program similar to Citizens of Oakland Responding to Emergencies (CORE) that would build relationships between the city and its residents, and creating neighbor-to-neighbor communication channels. Over the last year, the City has cultivated partnerships with organizations focused on fire safety and community preparedness. Among those groups is the Oakland Community Preparedness and Response, which is linked to the Oakland Firesafe Council, which is funded through grants from CAL Fire and the California Fire Foundation. Their website provides residents with awareness, educational workshops, detailed guides and "support to residents of the city of Oakland to help increase the overall community preparedness level and to improve disaster response capabilities. The City has the expressed approval of the Firesafe Council to promote their materials on our website and social media channels.

Socializing Fire Safety Tips and Information

In addition to the pages in development on the website, the City uses a range of public information tools to provide timely accurate information regarding emergency incidents and events. Unfortunately, sometimes the volume of options where people can gather information can have a negative impact as people may get confused or overwhelmed by the varying styles or volume of information available depending on the platform.

Currently, the City's public information team utilizes the following tools to reach Oakland's diverse constituencies:

- Facebook
- Twitter
- Instagram
- Nixel, used by OPD primarily to share crime prevention tips and traffic alerts
- KTOP (public access Television)
- Press Release to the City's media list
- NextDoor
- Active Campaign, an opt-in subscriber-based application used disseminate messages and newsletter style content from the City Administration.

In 2019, during the Public Safety Power Shutoff events, the public information team relied heavily on elected officials' ability to share timely information with their constituents via their newsletters and social media regarding power outages, timelines and projected impacts to city services. In turn, the City benefitted from hearing back from those elected officials and community partners about what information residents needed in real time, as opposed to after the fact.

Staff recognizes that there is no greater tool to support communication efforts than neighbors speaking with neighbors and trusted community organizations sharing well-crafted and accessible informational materials with their members, clients and supporters.

In addition to evaluating its communications tools, the City is consistently considering what the most appropriate sequence is for notifying the public of emergency events or issues in the community.

In Oakland, the City Administration has benefitted immensely from the dedicated groups, many of which are based in the high fire hazard severity zone and have made it their mission to promote and educate people on the very real threat that wildfire poses in based on Oakland's topography and its proximity to other threat zones. Over many years and to this day, these groups have been on the front lines promoting the annual inspection program, community preparedness and emergency response training, while providing critical guidance to City leaders and departments about the need for greater departmental alignment and focus in the area of wildfire prevention.

3) The Extent To Which Wildfire Prevention Will Be Addressed In The Next Updates To The City's General Plan, Safety, Open Space, Hazard Mitigation Plans And Other Similar Plans.

As mentioned above, the Strategic Planning Division within the Planning and Building Department is an active participant in the Working Group and, by definition, its efforts are primarily focused on planning efforts including the General Plan and its various elements as detailed below.

ADU Ordinance
A planning effort that is currently underway, is writing the new ordinance to conform to the recently passed State Laws for accessory dwelling units (ADUs) and incorporating regulations restricting ADUs in the Very High Fire Hazard Severity Zone, which are included in the S-9 Fire Safety Protection Combining Zone. As part of writing the ADU ordinance, planning staff is coordinating with both OFD and OakDOT.

Local Hazard Mitigation Plan
The City's Local Hazard Mitigation Plan will be updated by July of 2021 and the City will be reviewing and revising as necessary its wildfire prevention strategies. The plan will be led by the Emergency Management Services Division with the Strategic Planning Division assisting and coordinated with the Wildfire Prevention Working Group as well as the Department of Race and Equity along with outside agencies of Metropolitan Transportation Commission (MTC)/Association of Bay Area Governments (ABAG), East Bay Municipal Utilities District, East Bay Regional Parks District, and San Francisco Bay Conservation and Development Commission.

Housing Element and Safety Element
The City will be updating its' Housing Element and Safety Element as well as adopting a new Environmental Justice Element that are all due in December of 2022. As part of the update of these elements, the City will be reviewing and revising, where appropriate, its wildfire prevention strategies. Updating and creating these elements will involve the City Administrator's Office and a number of departments, including Planning and Building, Fire, Housing and Community Development, Human Services, Race and Equity, Public Works as well as outside agencies of MTC/ABAG, East Bay Municipal Utilities District, East Bay Regional Parks District, and San Francisco Bay Conservation and Development Commission.

Land Use and Transportation Element
The City will be updating the Land Use and Transportation Element (LUTE) as well as the Open Space, Conservation, and Recreation Element. Densities and subdivisions within the Very High Fire Hazard Severity Zone and S-9 Fire Safety Protection Combining Zone will continue to be

limited, and updates for wildfire prevention strategies will be analyzed as well. There will also be multiple departments involved in this effort including Planning and Building; Transportation; Public Works; Economic and Workforce Development; Parks, Recreation, and Youth Development; Race and Equity, Human Services, and Public Library along with outside agencies of MTC/ABAG, East Bay Regional Parks District, Alameda County Transportation Commission, and AC Transit.

PUBLIC OUTREACH / INTEREST

The work of wildfire prevention requires everyone to be involved, especially the public, as their actions are the most important to preventing wildfire. The Hill Area Neighborhood Councils regularly discuss wildfire prevention and the Neighborhood Services Coordinator for those beats is a member of the Wildfire Prevention Working Group. Also, the Fire Safe Council of concerned neighbors meets regularly and has a strong ongoing relationship with City staff. On August 31, a Joint District 1 and 4 Town Hall meeting was conducted during which the main components of this report were shared.

Because wildfire prevention is an ongoing task, this report is a living document and receiving public input helps shape more effective decisions by the team.

Respectfully submitted,

Joe DeVries, Director, Interdepartmental
Operations, Office of the City Administrator

For questions, please contact Joe DeVries, Director, Interdepartmental Operations, at (510) 238-3083.

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Oakland Vegetation Management Report (Revised Draft)

Link to the full document: https://cao-94612.s3.amazonaws.com/documents/Oakland-VMP_Revised-Draft_NOV-1-2019.pdf

1. Brief Staff Analysis

The latest "Revised Draft" of the Oakland Vegetation Management Plan (the "Plan") underscores the fact that the area within the Very High Fire Severity Zone (VHFSZ) is susceptible to Ground Fire, Surface Fire, and several types of Crown Fires. According to the Plan, the "topography, vegetation, and climatic conditions associated with the Plan Area combine to create a unique situation capable of supporting large-scale, high intensity, and sometimes damaging wildfires, such as the 1991 Tunnel Fire." The history of wildfires in the Plan Area is set forth at Table 5 on page 76 (please see below for a relevant excerpt from Plan at pages 74-79).

As Table 5 shows, four (4) of the last eighteen (18) wildfires have occurred in 2017 alone, indicating that the threat of wildfires is on the rise with global warming. Table 5 also shows that nearly all of the significant wildfires have burned in the months of September, October, and November. As the Plan states, "this timeframe coincides with the end of the dry summer season, where vegetation has lower fuel moistures and Diablo winds return to the Plan Area. While not all the fires shown in Table 5 were associated with Diablo (easterly or northeasterly) winds, the larges and most damaging fires have occurred during such winds."

The Plan makes clear that the unique topographic, vegetative and climatic conditions of the VHFSZ is such that its inhabitants are facing a "perfect storm" of fire risk conditions, while wildfire events are also increasing as a result of global warming.

In addition, the Plan notes that further exacerbating this risk is the challenging "disadvantages" of road infrastructure and housing density. The Plan describes the "land use within the City's VHFSZ that creates conditions that can be described as either a wildland urban interface or a wildland urban intermix." The area where urban development abuts vegetative fuels is known as the wildland urban interface (WUI). This condition exists within the City's VHFSZ where structures abut City parklands and open space. Areas where the density of housing units

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and structures is lower and/or the space between structures consists of vegetative fuels capable of propagating fire are more typically characterized as a wildland urban intermix (Intermix).

The Plan notes that the "WUI disadvantages" to the Oakland Fire Department (OFD), and its efforts at fire suppression, consist of the following:

WUI Disadvantages

- High housing density
- Congested roads during emergencies
- Limited options if the community water systems fail

Conversely, the Wildland Urban Intermix "advantages" cite "low housing density" as one of the area's "advantages" in fighting fire suppression, while the Plan lists the following "disadvantages" to the Intermix area:

Intermix Disadvantages

- Increased Risk to firefighters
- Emergency equipment can only protect single assets
- Delayed emergency equipment response times due to:
    - Rural roads (single lane, windy, heavy fuel loading)
    - Long driveways
- Congested roads during emergencies
- Diversity in water supply systems
- Housing surrounded by vegetation

As set forth above, the "disadvantages" to fire suppression in both areas is related to "housing density," water supply, and congested and challenging road infrastructure. As supported by OFD and the Plan, adding more human population to these areas, in the form of additional housing and population, will only further exacerbate the "disadvantages" to fire suppression and create further life safety dangers in the VHFSZ. Further, as laid out in Table 5, the wildfire danger is only increasing in recent years, with over 20% of the last century's wildfires occurring in 2017. All of this evidence, in addition to evidence provided by OFD on the record, supports a prohibition of ADU development in the VHFSZ in order to limit human population, housing density, and the risk of congested road infrastructure so that OFD can stand the best chance at fire suppression when the next wildfire occurs in the area.

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2. Relevant Excerpt from Vegetation Management Plan

2.4 Fire History and Ignitions

Fire history is an important component in understanding fire frequency, fire type, significant ignition sources, and vulnerable areas. The topography, vegetation, and climatic conditions associated with the Plan Area combine to create a unique situation capable of supporting large-scale, high-intensity, and sometimes damaging wildfires, such as the 1991 Tunnel Fire. The history of wildfires in the Plan Area is presented in Table 5.

Table 5
History of Wildfires in the Oakland Hills

Year	Month	Wind	Acres	Structures Lost	Location
1923	September	Diablo	130	584	North of UC Berkeley Campus
1931	November	Diablo	1,800	5	Leona Canyon
1933	November	Diablo	1,000	5	Joaquin Miller
1937	September	Westerly	700	4	Broadway Terrace
1940	September	Westerly	30	0	Broadway Terrace
1946	September	Diablo	1,000	0	Buckingham/Norfolk
1955	November	Westerly	10	0	Montclair
1960	October	Diablo	1,200	2	Leona Canyon
1961	November	South-Westerly	400	0	Briones Regional Park, Tilden Regional Park, Roberts Regional Recreation Area, Chabot Regional Park
1968	October	Westerly	204	0	North of Naval Hospital
1970	September	Diablo	204	37	Buckingham/Norfolk
1980	December	Diablo	2	5	Wildcat Canyon Road, Berkeley
1990	October	Westerly	200	0	Leona Canyon
1991	October	Diablo	1,700	3,000	Buckingham/Norfolk
2017	July	West/North	9	0	Grizzly Peak and South Park
2017	September	North	22	0	Leona Quarry
2017	October	Diablo	7	0	Elysian Fields and Gold Links Road
2017	December	Diablo	2.5	2	Snake Road and Colton Boulevard

Source: City of Oakland 2017b.

As presented in Table 5, nearly all significant wildfires have burned in the months of September, October, or November. This timeframe coincides with the end of the dry summer season, where vegetation has lower fuel moistures and Diablo winds return to the Plan Area. While not all the fires shown in Table 5 were associated with Diablo (easterly or northeasterly) winds, the largest and most damaging fires have occurred during such winds.

The history of wildfire ignitions in the Plan Area is directly related to human activity. Notable ignition locations include view spots along Grizzly Peak Boulevard or Skyline Boulevard that offer views of the San Francisco Bay and congregation areas within Joaquin Miller Park, along

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Skyline Boulevard near Sequoia Point. Stolen vehicle dump sites are another potential wildfire ignition source, with notable locations in Joaquin Miller Park (near Sequoia Point) and at the water tank on Skyline Boulevard, approximately 0.5 miles west of its intersection with Grass Valley Road, near the entrance to Knowland Park. Mechanized and power equipment use (e.g., mowers) on private, residential parcels is another potential ignition source, one that was responsible for igniting the 1970 Diablo Fire. Fireworks present another potential ignition source in early summer on or near July 4, notably at King Estate Open Space Park (Crudele, pers. comm. 2017). Joaquin Miller

2.5 Fire Hazard Severity Zoning

As noted, the Plan Area is located within the City's adopted VHFHSZ. Fire Hazard Severity Zones (FHSZs) are "geographical areas designated pursuant to California Public Resources Codes, Sections 4201 through 4204 and classified as Very High, High, or Moderate in State Responsibility Areas or as Local Agency Very High Fire Hazard Severity Zones designated pursuant to California Government Code, Sections 51175 through 51189" (California Building Standards Commission 2016). Oakland's VHFHSZ is a Local Agency VHFHSZ, as defined, and the City is considered a Local Responsibility Area (LRA). OFD is the responsible agency for fire protection within the City's VHFHSZ. The Plan Area abuts lands where the responsibility for fire protection lies with the State of California (State Responsibility Areas (SRA)). The boundary of SRA lands proximate to the Plan Area is depicted in Figure 2.

California Public Resources Code Sections 4201–4204 and Government Code Sections 51175–51189 direct California Department of Forestry and Fire Protection (CAL FIRE) to map areas of significant fire hazards based on fuels, terrain, weather, and other relevant factors. The resulting FHSZs define the application of various mitigation strategies to reduce risk associated with wildland fires (CAL FIRE 2016a). The model used to determine the extent of FHSZs is based on an analysis of potential fire behavior, fire probability predicated on frequency of fire weather, ignition patterns, expected rate of spread, ember (brand) production, and/or past fire history (CAL FIRE 2016a). Structures built in FHSZs are subject to more stringent fire hardening requirements than those that are not.

2.6 Wildland Urban Interface/Intermix

The pattern of development and land use within the City's VHFHSZ creates conditions that can be described as either a wildland urban interface or a wildland urban intermix. Urban areas are predominantly built-up environments with little or no exposure to vegetative fuels. Such areas are located primarily to the west of the City's VHFHSZ. The area where urban development abuts vegetative fuels is known as the wildland urban interface (WUI). This condition exists within the City's VHFHSZ where structures abut City parklands and open space. Areas where the density of housing units and structures is lower and/or the space between structures consists of vegetative fuels capable of propagating fire are more typically characterized as a wildland urban intermix (Intermix). This condition exists throughout the City's VHFHSZ, notably where smaller undeveloped lots consisting of vegetative fuels are situated between structures. Both conditions present advantages and disadvantages with respect to reducing wildfire hazard, as described below.

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2.6.1 Wildland Urban Interface

WUI areas are those within the “vicinity” of wildland vegetation. The wildland fire risk associated with WUI areas includes propagation of fire throughout WUI communities via house-to-house fire spread, landscaping-to-house fire spread, or ember intrusion. Advantages and disadvantages associated with WUI areas are as follows.

WUI Advantages

- Community water supply systems in place
- Multiple homes accessed by a single road
- Emergency equipment protects multiple assets at once
- Houses usually only exposed to flammable fuels on one side

WUI Disadvantages

- High housing density
- Congested roads during emergencies
- Limited options if the community water systems fail

2.6.2 Wildland Urban Intermix

Intermix areas are those where housing and vegetation intermingle. In the Intermix, wildland vegetation is continuous, and more than half of the land area is vegetated with combustible fuels. The wildland fire risk associated with Intermix areas includes vegetation-to-house fire spread or ember intrusion. Advantages and disadvantages associated with Intermix areas are as follow.

Intermix Advantages

- Low housing density
- Diversity in water supply systems

Intermix Disadvantages

- Increased risk to firefighters
- Emergency equipment can only protect single assets
- Delayed emergency equipment response times due to:

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  - Rural roads (single lane, windy, heavy fuel loading)
  - Long driveways

- Congested roads during emergencies

- Diversity in water supply systems

- Houses surrounded by vegetation

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CITY OF OAKLAND
Office of the City Administrator

1 Frank H. Ogawa Plaza, 11th Floor • Oakland, CA 94612

Joe DeVries, Director, Interdepartmental Operations
Email: jdevries@oaklandca.gov
Phone: 510-238-3083
Fax: 510-238-7084

To: William A. Gilchrist, Director, Planning and Building Department
Re: Accessory Dwelling Unit (ADU) Planning Code Amendments and Restrictions in the High Fire Severity Zone
Date: August 20, 2021

Director Gilchrist,

I am offering this letter of support for the revised staff proposal regarding the ADU Planning Code Amendments and the restrictions that are included on parcels located in the High Fire Severity Zone. As you know, the City Council adopted Resolution 87940 C.M.S. in 2019 declaring Wildfire Prevention as a top priority for the city and this led to the creation of the Wildfire Prevention Working Group. The Working Group includes several departments to ensure we take a comprehensive approach to prevention and that has elevated the importance of the Planning Department’s contribution to prevention through appropriate zoning restrictions.

In recent years, the Fire Department and Department of Transportation conducted an inventory of streets in the High Fire Severity Zone and identified multiple “choke points” where it is very difficult for a fire engine to get through.

However, in the wake of the tragic Camp Fire that swept through Paradise, CA, fire departments everywhere are seeing that evacuation routes quickly become overwhelmed in a fast-moving fire. Adding ADUs and creating a higher level of density would be dangerous to everyone in those communities, including the very people the new ADUs are designed to serve.

Planning Staff, in partnership with the Fire Department brought forward a proposal this summer to restrict ADUs in the Very High Fire Severity Zone and heard the concerns raised by the Planning Commission that the restrictions went too far. The staff went back to work with the requested approach that the restrictions be refined and made more precise. I believe they have revised the proposal with that precision in mind and are presenting a new option that balances the need to responsibly address California’s housing crisis and protect Oaklanders from the very real threat of wildfire.

I want to praise the staff for their responsiveness and the Planning Commission for suggesting we strike a better balance. I believe the new proposed option captures that balance and is a thoughtful path forward.

In partnership,

Joe DeVries, Director, Interdepartmental Operations
Office of the City Administrator

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CITY OF OAKLAND

LIONEL J. WILSON BUILDING ● 150 FRANK H. OGAWA PLAZA, SUITE 3354 ● OAKLAND, CA 94612

Office of the Fire Chief (510) 238-4084
Reginald D. Freeman

To: William A. Gilchrist, Director, Planning and Building Department
Re: Accessory Dwelling Unit (ADU) Planning Code Amendments and Restrictions in the High Fire Severity Zone

Date: October 26, 2021

Dear Council President Bas and Members of the City Council,

I am offering this letter of support for the revised staff proposal regarding the ADU Planning Code Amendments and the restrictions that are included on parcels located in the Very High Fire Hazard Severity Zone (VHFHSZ).

Oakland's history of wildfires is no secret in California, the Oakland firestorm of 1991 was one of the largest urban wildfires in history. The fire started on the border of Oakland and spread throughout the Berkeley hills. Ultimately 25 lives were lost, 150 people were injured, 1,520 acres of land was burned, and thousands of homes were destroyed. The high winds, steep terrain, and heavy fuel load made fighting this historic blaze a major challenge. The economic loss from the fire was estimated at $1.5 billion.

Nearly 30 years later, with the clear intent to align City departments in the interest of safety and preparedness, City Council adopted Resolution 87940 C.M.S. in 2019 declaring Wildfire Prevention as a top priority for the city and this led to the creation of the Wildfire Prevention Working Group. The strategic working group entrusts several departments to ensure Oakland is taking a coordinated approach to prevention. That has elevated the importance of the Planning Department's contribution to prevention through appropriate zoning restrictions. The working group meetings cover a range of issues related to immediate fire safety challenges, ongoing hazard mitigation, with a strong emphasis on coordination between departments and nearby jurisdictions, and community stakeholders.

Now more than ever, Oakland residents and communities throughout the region are looking for their government to take proactive steps to increase and promote public safety and reduce wildfire risk. A surge in ADUs in the VHFHSZ project put new and existing residents at risk during mass evacuations during wildfires. .

It remains the belief of the working group that adding ADUs and creating a higher level of density, fuel load, and congestion in the fire prone Oakland hills will be hazardous to everyone in the high fire risk communities, including the very people the new ADUs are designed to serve.

It is important to note that the Fire Department is not making this recommendation in vacuum. The Fire Department conducts a range of actions on an annual basis that have played a critical role in preventing Oakland from experiencing the types of wildfire events that we continue to see in cities across California and in neighboring states. Those actions include:

- Proactive annual inspections of over 25,000 privately, city-owned and vacant parcels.

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- Deploying one of the largest goat herds in the state. Each year goats prove to be a valuable and cost-effective fire prevention tool. In 2021, goats have cleared approximately 900 acres of hazardous and hard to reach dry vegetation.
- Contracting with vendors each year to mitigate hazardous vegetation on city owned property, clearing 60 miles of vegetation along roadways in addition to hundreds of acres of vegetation on public parcels.
- For the last two years, over July 4th weekend in partnership with neighboring jurisdictions, Oakland Fire and Oakland Police have proactively closed stretches of roadways and scenic lookouts along both Grizzly Peak and Skyline boulevards to prevent large gatherings and hazard activity and stop illegal parking that might cause delays in emergency responses along that hillside corridor.
- Closing parks, upstaffing fire crews, doing roving patrols, and pushing out extensive public messaging during Red Flag Warning and extreme weather events.
- Establishing the Fire Safe Streets Program with the city's Department of Transportation whereby the two departments have conducted an inventory of streets in the High Fire Severity Zone and identified multiple "choke points" where it is very difficult for a fire engine to get through. Once identified, the departments begin the lengthy process of conducting outreach to residents about proposed changes to parking restrictions, signage, and enforcement.
- Launching the Know Your Zone campaign in partnership with Zonehaven. Now every Oakland resident lives in an evacuation zone identified by a number so they can stay informed in the event that their community is being evacuated.

Planning Staff, in partnership with the Fire Department brought forward a proposal this summer to restrict ADUs in the Very High Fire Severity Zone. We heard the concerns raised by the Planning Commission that the restrictions went too far. The staff went back to work with the requested approach that the restrictions be refined and made more precise.

Following an extensive evaluation process, the Fire Department holds firm that prohibiting the the development of ADU's in the CAL Fire designated VHFHSZ is the best approach to preventing loss of life and property to wildfire. However, I believe that staff have been thoughtful and diligent in their efforts to identify two options that balance the need to responsibly address California's housing crisis and protect Oaklanders from the very real threat of wildfire.

I wish to recognize the dedicated staff for their responsiveness and the Planning Commission for their consideration of this important issue. I encourage members of the City Council to contact me with any questions, comments, or concerns regarding the Fire Department's position on this issue.

Thank you for your consideration,

Reginald D. Freeman

Reginald D. Freeman

Chief, Oakland Fire Department

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ATTACHMENT G

Title

Developing Transportation Response Strategies for Wildfire Evacuations via an Empirically Supported Traffic Simulation of Berkeley, California

Permalink

https://escholarship.org/uc/item/70p6k4rf

Authors

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Wong, Stephen D

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ATTACHMENT G

Developing Transportation Response Strategies for Wildfire Evacuations via an Empirically Supported Traffic Simulation of Berkeley, California

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Transportation Research Record

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Note: Small differences in language will exist between this version and the final published journal article

Developing Transportation Response Strategies for Wildfire Evacuations via an Empirically Supported Traffic Simulation of Berkeley, California

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Funding Statement: SB 1 grant from the University of California Institute of Transportation Studies, the Graduate Research Fellowship Program (National Science Foundation), and the Dwight D. Eisenhower Transportation Fellowship Program (Federal Highway Administration).

Open-source Code: https://github.com/cb-cities/spatial_queue

ABSTRACT

Government agencies must make rapid and informed decisions in wildfires to safely evacuate people. However, current evacuation simulation tools for resource-strapped agencies largely fail to compare possible transportation responses or incorporate empirical evidence from past wildfires. Consequently, we employ online survey data from evacuees of the 2017 Northern California Wildfires (n=37), the 2017 Southern California Wildfires (n=175), and the 2018 Carr Wildfire (n=254) to inform a policy-oriented traffic evacuation simulation model. We test our simulation for a hypothetical wildfire evacuation in the wildland urban interface (WUI) of Berkeley, California. We focus on variables including fire speed, departure time distribution, towing of items, transportation mode, GPS-enabled rerouting, phased evacuations (i.e., allowing higher-risk residents to leave earlier), and contraflow (i.e., switching all lanes away from danger).

We found that reducing household vehicles (i.e., to 1 vehicle per household) and increasing GPS-enabled rerouting (e.g., 50% participation) lowered exposed vehicles (i.e., total vehicles in the fire frontier) by over 50% and evacuation time estimates (ETEs) by about 30% from baseline. Phased evacuations with a suitable time interval reduced exposed vehicles most significantly (over 90%) but produced a slightly longer ETEs. Both contraflow (on limited links due to resource constraints) and slowing fire speed were effective in lowering exposed vehicles (around 50%), but not ETEs. Extended contraflow can reduce both exposed vehicles and ETEs. We recommend agencies develop a communication and parking plan to reduce the number of evacuating vehicles, create and communicate a phased evacuation plan, and build partnerships with GPS-routing services.

Keywords: Evacuations, Traffic Simulation, California Wildfires, Transportation Policy, Behavior, Contraflow, Phased Evacuations

1. INTRODUCTION

Recent large-scale wildfire evacuations in California have exposed significant challenges for governments in increasing evacuation compliance, decreasing congestion, and ensuring equity. In many of these events, public agencies (e.g., transportation, transit, emergency management) lacked resources to deploy for a transportation response (1). These challenges are likely to extend to other wildland-urban interface (WUI) evacuations across North America. Without adequate funding, staff, and research ability, governments need practice-ready strategies to successfully evacuate residents in wildfires. One positive direction in the field has been the development of wildfire evacuation models, including traffic simulation models (2) that have sometimes been coupled with fire spread models and trigger buffer models (e.g., (3)). Despite these new integrated models, two key limitations remain in the wildfire evacuation simulation field. First, choice-making and behavior (e.g., transportation mode choice, destination choice) in wildfire evacuation simulations is often assumed or estimated based on expert knowledge, not actual behavior from post-disaster surveys or data. Second, traffic simulations for wildfires often fail to compare transportation strategies for evacuations. Effective and cost-efficient policies are crucial for ensuring safe evacuations.

To begin addressing these two key limitations, we developed several research questions:

1. What behavioral assumptions in simulations could be replaced by previously collected evacuation data?
2. What key factors should be integrated into traffic simulations to balance realism, computational complexity, and generalizability?
3. What transportation responses/strategies could be simulated and how might responses/strategies differ?

To answer these questions, we developed a spatial-queue-based traffic simulation that integrates post-disaster wildfire survey data from three wildfires - the 2017 Northern California Wildfires, the 2017 Southern California Wildfires, and the 2018 Carr Wildfire - for several evacuation choices. Using this simulation, we compare and contrast different fire speeds, departure times, towing demand, transportation mode splits, rerouting participation rates (i.e., GPS-guided routing based on real-time traffic conditions), phased evacuation times (i.e., time-based zone releases of evacuees), and contraflow options (e.g., switching all lanes to evacuate away from the fire). These fire behavior and policy parameters are tested in hypothetical wildfire incidents in the Berkeley Hills. We investigate the results for each scenario and provide recommendations for the different responses and strategies.

2. LITERATURE REVIEW

2.1 Wildfire and No-Notice Evacuation Behavior

During wildfire evacuations, individuals must make a number of complex choices including their decision to evacuate or stay/defend, departure timing, transportation mode, route choice, shelter/accommodation type, destination, and reentry timing. The wildfire evacuation behavior literature (see review in (4)) has focused predominantly on the decision to evacuate or stay (5,6). In many cases (e.g., (7,8)), this literature employs discrete choice models to isolate influential variables in the decision to evacuate or stay including defending behavior of property (see (9) for more work on alternatives to evacuations). One important improvement over the years has been the collection of post-disaster wildfire evacuation survey data to inform these models, e.g., (6–8,10,11,1). However, much less work has focused on decisions during the evacuation process (e.g., route, destination) (11,12), as noted in (13). Other work, such as (14), notes that behavior such as extra-trip making, mobilization time, and background traffic can also impact evacuations. Moreover, alternative transportation strategies such as the sharing economy (e.g. (15–17)) may be feasible under certain wildfire evacuation circumstances, changing the potential modal split and sometimes increasing social equity. Altogether, the literature lacks in several areas: 1) fully understanding evacuee behavior, and 2) having enough survey data for most or all choices in wildfire evacuations. In addition, survey data has yet to be fully integrated into evacuation simulation models as behavioral variables are currently created via assumptions, expert opinions, and/or hypothesized statistical distributions.

Apart from the wildfire specific studies referenced above, no-notice or short-notice evacuation under other types of hazards (e.g., truck attack, flash flood, or general emergency situations) have long attracted researchers' attention (18–21). Research in this area can be categorized into two types. The first type focuses on understanding the evacuation demand, such as participation rates, origin locations, departure times, and destination locations (22). The second type analyzes operational strategies to accomplish the evacuation safely and efficiently (23). On the demand side, compared to early, self-organized evacuations, no- or short-notice evacuations are often characterized by excess levels of stress and uncertainties associated with dire situations (20,24). As a result, evacuees' behaviors might differ from their response to long-notice evacuations. In addition, short-notice evacuations also have distinct phases (e.g., anticipation, warning, displacement, notification, and return and recovery) (24). Different evacuation behaviors are associated with each phase. Surveys and statistical models have been used to elicit qualitative and quantitative insights on the evacuation behavior parameters, such as the reasons and ratios of people choosing to stay in shelters, hotels, or with family/friends (22,24). It is also recognized that different behavior parameters are interconnected and correlated, and models with correlation structures have been used to capture their joint distribution (22). On the operational side, challenges for safely evacuating people correspond to traffic assignment tasks, with some additional features and constraints. Different algorithms have been used to optimize the evacuation process, from bus scheduling, to family trip-chain arrangements, to optimum traffic assignment (21,23,25).

2.2 Wildfire Evacuation Strategies

Wildfire evacuation strategies have been largely developed following guidance and lessons learned from other types of disasters (e.g., hurricanes, tsunamis). The focus of most strategies for wildfire evacuations has been on evacuation efficiency (e.g., reducing evacuation time estimates [ETEs] or total travel time), given the speed and short notice of wildfires. Generally, these metrics are aimed to 1) improve the network capacity through strategies of contraflow (e.g., switching some or all lanes of a roadway to flow away from a hazard) or new infrastructure or 2) optimize the utilization of the network by evacuees through strategies such as phased evacuation, which reduces peak demand on the roadway by spreading out evacuees temporally. Some examples in literature offer more details of how the strategies can be implemented in a wildfire evacuation context. Contraflow was studied in (14), where locations were determined by iteratively turning the excess road capacity in the opposite direction of road links. (26) proposed a phased-evacuation strategy where those closer to danger should leave first (Innermost First Out, InFO), while (27) tested all phase sequences in a road network with four evacuation zones. A lane-based intersection-control plan was proposed in (28) to reduce crossing and merging conflicts at intersections for wildfire evacuations. However, one key limitation of many of these strategies is the need for a significant amount of personnel and coordination to implement (e.g., intersection control in (29)). Moreover, some metrics to determine strategy efficiency can be misleading as ETEs are sensitive to the departure of the last vehicle from the evacuation zone (30). Despite work on different transportation strategies in evacuations (63), a comprehensive study that compares relative gains of each type of strategy specifically for wildfire evacuation remains absent from the literature.

2.3 Wildfire Evacuation Simulations and Strategies

Traffic modeling and simulations have been widely used to test wildfire evacuation scenarios and strategies (Table 1), from simple hypothetical network (27,29), to small communities with tens to hundreds of households (31,32) to a large town/city (33). Most studies run off-the-shelf microscopic simulation software, such as SUMO (33) and Paramics (29,31). Certain non-microsimulation quick calculations are also proven to be useful in estimating the evacuation delays and finding bottlenecks, such as the simplified manual calculations in (29) and adjusted four-step models used by (14). Model inputs (network and travel demand) are usually sourced from a variety of venues, such as the OpenStreetMap (OSM), digitized aerial imagery, planning documents, and census data. Vehicles follow either a fixed route to the closest exits or routes that periodically update based on evolving traffic conditions during the evacuation. Probably due to the complexity of the problem as well as the emerging nature of the evacuation process, most wildfire-evacuation-related studies use one-shot assignment rather than optimization-based formulation, with exceptions for simplified networks, such as in (28) and (34). Model outputs typically include aggregated metrics such as ETEs, fire exposure (e.g., (27)), or spatially or temporally disaggregated link-level congestion status (e.g., (14,33)). In many evacuation studies across hazards, agent-based models are widely adopted in the evacuation simulations (35–37). These types of models are frequently leveraged to investigate the changes in evacuation performance metrics in parametric studies by focusing on detailed evacuation choices, such as departure time, route, and destination.

TABLE 1 Key Models for Wildfire Evacuations

Traffic Simulation Models for Wildfire Evacuations							
Reference	Model Characteristics					Metrics	Strategies or Scenarios
	Demand Generation	Departure Time	Destination and Routing Choices	Simulation Type	Network + Demand Data Source		
(31)8/11/2021 8:14:00 AM	250 homes; vehicles per household follows Poisson distribution (mean: 0.5-3 vehicles/household)	Household departure time follows Poisson distribution (mean: 5-25 minutes)	Dynamically updated least-cost routes to closest exits	Microscopic (Paramics)	Digitized aerial image and planning documents (Emigration Oak, UT)	Clearance time, mean vehicle travel time, evacuation time of each household (disaggregated)	Adding new infrastructure; varying demand rate and departure delay
(29)*	Not required; 30-150 vehicles per zone used for testing the clearance time on the hypothesized network	Not required; uniformly generated within 15 minutes; used for testing the clearance time on the hypothesized network	Various static routing (minimize total travel distance, minimize merging or balanced); destinations solved endogenously with routes	Microscopic (Paramics) and manual capacity analysis	Hypothesized (9 to 25 intersections); digitized aerial image of 20 intersections (Salt Lake City, UT)	Clearance time, total travel distance, number of merges	Reducing intersection merge/cross delays via turn restrictions (lane-based routing); varying demand rate, signal timing and numbers of exits
(34)*	Three levels of evacuation demand: 1,794, 3,558, and 5,692. Background traffic and evacuees are in total 47,300	Optimum departure time solved endogenously with routes	System-optimal dynamic traffic assignment; destinations solved endogenously with routes	Mesoscopic (DYNASMART-P) for network loading	Simplified extracted network (Fort Worth, TX)	Network clearance time, total and average trip time	Time-dependent staging policy for each origin; varying evacuation demand
(32)	1.5-5 vehicles per node, randomly assigned to 753 nodes	All departure finish by 30 minutes (urgent), 1 hour (medium), or 2 hours (slow)	Fixed "shortest" path or dynamically updated "fastest" path to pre-designated exits	Microscopic (CORSIM)	Digitized aerial photograph (Summit Park, Salt Lake City, UT)	Clearance time, fatalities, link level max. queue length	Varying demand rate, departure time (urgency), & incorporating rerouting
(27)*	Grid network: 20-80 vehicles per block; Ring network: same vehicle density as the grid network; real network of 1-8 vehicles per household for 485 households	Set zonal departure time interval: hypothesized network: 1 minute; real network: 1 or 4 minutes	Dynamically updated fastest route to any exit; all exits are linked as one destination zone.	Microscopic (Paramics)	Hypothesized (grid, ring); digitized aerial image (San Marcos, TX)	Clearance time	Staggering departure of zones; varying demand rate

(14)	All households in 8 evacuation districts with background traffic; auto ownership from US Census (2000)	Not available (static)	Shelters (15%), Friends or families' home (60%), hotels (15%), out of county (10%)	Adjusted four-step with static multiclass assignment	Planning documents of main roads for fire-prone neighborhoods (Colorado Spring, CO)	Clearance time, link-level congestion (volume-to-capacity)	Restricting the egress routes to evacuees; blocking the entrance to evacuation zones; conducting contraflow
(38)	Total population of about 9,000. 85% participate in the evacuation, 1.5 people per vehicle trip	Evacuees react to visual triggers & official warnings, both related to dynamic fire front; decision and preparation delay	Static routing to closest exits	Microscopic (SUMO) with trigger model	Open Street Maps (OSM); census population; registered household addresses (Dandenong Ranges, Australia)	Clearance time, fire exposure count	Conducting phased evacuation with dynamic triggering, varying fire ignition locations and weather conditions
(33)	Uniformly distributed along residential/service roads (23,635 vehicles for Paradise, 12,212 for Mill Valley)	S-shaped cumulative departure	Fixed "shortest" path or periodically updated "fastest" path to any exit; all exits are linked as one destination zone.	Microscopic (SUMO) 1 second time step is used).	OSM (Paradise, CA and Mill Valley, CA)	Link-level speed, arrival curve, average trip-time	Closing roads; conducting contraflow, varying departure time concentration; varying demand rate, and rerouting

* Emergency evacuations, not specific to wildfire evacuations

Other Key Literature Related to Simulations of Wildfire Evacuations

Reference	**Type of Model or Analysis**	**Goal or Aim of Study**
(39)	Fire spread modeling (FlamMap), fire-spread network modeling, and shortest path analysis (altogether known as the Wildland-Urban Interface Evacuation model)	Calculate evacuation trigger buffer a small community (Julian, California) and determine trigger zones
(40)	Wildland-Urban Interface Evacuation model (WUIVAC)	Apply data from the 2003 Cedar Fire in southern California to develop trigger buffers and compare results to the event timeline to find possibly improvements
(41)	Network and spatial data analysis (critical cluster model)	Identify fire-prone communities with minimal egress opportunity in western U.S.
(3)	Household-level model for trigger buffers and fire-spread modeling (FlamMap)	Determine evacuation trigger buffers (ETBs), recommended evacuation departure times (REDTs), and a ranking of households based on lead time
(42)	Review of evacuation models	Understand and review the scale, applicability, and interactions of fire, pedestrian, and traffic models
(2)	Review of traffic models for wildfire evacuations	Understand and review the traffic models based on relation to fire spread, spatial and demographic factors, temporal issues, and intended application and identification of 22 traffic models and applications
(43)	Controlled behavior experiment and regression models	Determine the collective evacuation decision of communities under different disaster likelihoods and shelter availabilities

2.4 Evacuation issues in other disasters

Evacuation strategies in wildfire emergencies can sometimes be different compared to other disasters, due to characteristics of fire hazards. For example, time for advanced warnings in wildfire evacuations (hours) are often shorter than those for hurricanes and flooding (often with at least 24 hours in advance), but longer than tsunami evacuations (minutes in advance or no warnings at all). The spatial extent of evacuations for each hazard are also different, where the distances of evacuation trips include local sheltering (e.g., tsunamis), within-region evacuations (e.g., wildfires), and out-of-state evacuations (e.g., hurricanes). These spatial temporal differences along with the difference in risks (63) alters evacuation behavior and the most efficient and effective transportation response strategies. For example, compared with wildfire evacuations when cars are the predominant mode of transport, tsunami evacuations are usually multi-modal, involving both vehicular traffic and pedestrian traffic as people need to rapidly move to safety (35). Tsunami evacuation destinations also tend to be closer in distance (to inland location or vertical shelters), due to the minimal time to evacuate (36). Hurricane evacuations benefit from a longer period of advanced warning (e.g., usually days in advance), but the spatial extents of the evacuation trips are also the largest, sometimes requiring evacuations of over 100 miles to another state (44,45). This can lead to large-scale transportation responses that span multiple states. While wildfires often require more rapid evacuations compared to hurricanes, they also tend to impact a smaller land area, threaten less people, and require shorter trips to reach a safe destination. Consequently, wildfire evacuation transportation responses must be deployed faster than hurricane responses, but they can also be more complex and time-intensive compared to tsunami evacuations.

Other types of disasters, such as nuclear power plant failures, chemical accidents, and hazardous material accidents, also require evacuations. In nuclear power plant failures (e.g., the Three Miles Island (TMI) nuclear accident, USA [1979] and the Fukushima nuclear disaster, Japan [2011]), individuals evacuated lived in specific distances from the source of the accident. For example, residents within several to tens of miles radius of the accident were ordered to evacuate in past events (46,47). Since the direction of radioactive material plays a critical role, the strategies employed could be parallel to those of wildfires. However, shelter-in-place strategies (e.g., staying inside and reducing air flow into a building) are more common for these disasters than wildfires. It should also be noted that the temporal length of evacuations from these types of disasters is highly variable (46,48), which indicates that different evacuation strategies from a range of natural hazards could be used. Altogether, the unique characteristics of hazards influences the most effective transportation response strategies to improve evacuation outcomes. However, strategies developed for one disaster could be effective for another disaster with similar spatiotemporal characteristics. To test this possibility for wildfire evacuations, we considered a number of strategies across hazards to begin developing a suite of evacuation strategies that are most effective for wildfires.

3. METHODOLOGY

To address some gaps presented in the literature review and taking cues from (2), we developed a survey-informed dynamic (spatial-queue) traffic simulation to evaluate evacuation performance (time efficiency, evacuee safety) under different fire, human behavior, and transportation response scenarios. The details of each component are introduced below in Figure 1 and following sections.

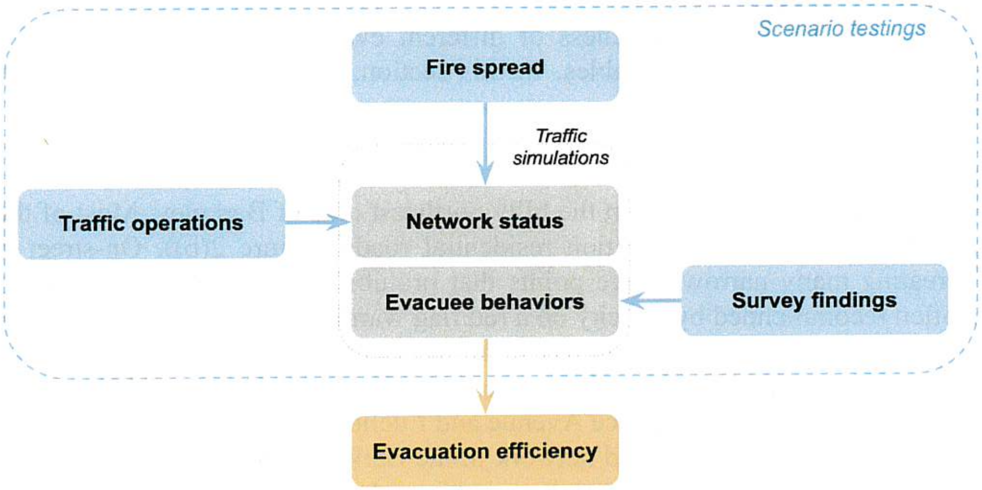


Figure 1. Study framework

3.1 Spatial-Queue-Based Dynamic Traffic Simulation Model

We use a spatial-queue-based traffic model to simulate the evacuation process. We chose this over popular microscopic simulators that implement car-following and lane-changing because the spatial-queue-based model is less data intensive and is easier to program from scratch. The simulator tracks individual vehicles through a vehicle routing module, a spatial-queue-based link model, and an intersection model that prevents cross conflicts. The simulation runs at a time step of 1 second, capturing detailed temporal traffic conditions, though not sub-link, sub-node or sub-second behavior (e.g., interaction of multiple vehicles inside an intersection). At the beginning of the simulation (or when rerouting is required), the routing module computes for the fastest path using Dijkstra's Algorithm (49), based on the free flow speed (initial route) or average travel speed in the past 20 seconds (subsequent rerouting). Vehicle routes are updated every 10 seconds for those following real-time traffic updates similar to location-based direction services (e.g., Google Maps, Apple Maps, Waze). Queues and spillbacks are simulated by the link model, which requires a vehicle to spend at least the free flow travel time on a link, before joining a queue at the end. When the end of the queue, formed by vehicles with some physical length, reaches the upstream end of the link, no more vehicles can enter (spillback). Link flow capacity is assumed to be 1,900 vehicles/(hour×lane). Discretized into one-second time steps, link capacities are imposed in a flip-coin probability manner, with the probability of a queuing vehicle leaving the current link or entering the next link being 0.53 vehicles/(second×lane). At each 1-second time step, the node model moves vehicles at the front of each link to the next link, as long as 1) it satisfies the inflow capacity of the next link and the outflow capacity of the current link, and 2) it does not conflict with other vehicles moving through the intersection at that time step (e.g., from perpendicular direction, left-turns). Vehicles entering an intersection are assumed to have equal priority except roundabouts (higher priority). All intersections are modeled as non-signalized (e.g., due to power failures).

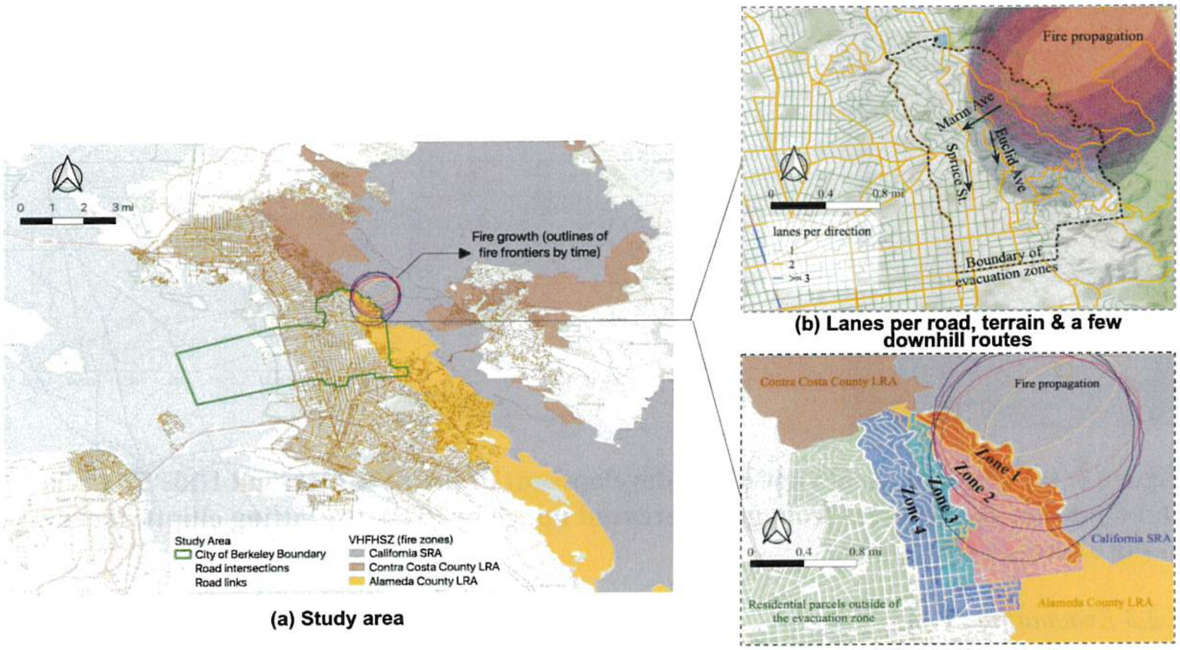
3.2 Scenario Development

This research compares the effectiveness of different evacuation response/policy options via scenario testing with controlled variables. In this section, the set of fixed inputs and variable scenarios will be explained.

3.2.1 Road Network

The hypothesized evacuation occurs in the hilly northeast area of Berkeley. Most of the roads in the study area are one-way-per-direction residential roads (Figure 2(b)). On-street parking is common, creating many narrow choke points that prohibit two-way flow. However, off-street parking is often recommended by the city on a red flag warning day (50). Figure 2(b) highlights a few main evacuation routes. Among all possible routes leading away from the fire, Marin Avenue is the straightest (no curve), but is also the steepest (maximum gradient over 30%). The other two roads labeled in Figure 2(b) (i.e., Spruce Avenue and Euclid Avenue), are also frequently used by residents. A distinct feature of the road network in the Berkeley Hills compared to other wildfire evacuation study is that the road network here is "funnel-shaped." Apart from the major egress roads shown in Figure 2(b), there are many smaller roads that lead to safe areas. These roads can serve as the evacuation route for a small number of vehicles that are routed off the main roads, while also allowing for emergency access vehicles to go uphill if major roads are used for contraflow operations. We also note that nearly all roads in the area are flanked by densely grown trees and brush, which pose substantial fire risk and a high chance for toppled trees on roadways.

The road network for the study area was obtained from the OSM. The study area is defined to be the city of Berkeley plus a 6.2-mile (10 km) buffer area, given wildfire evacuation trips are usually short (1,14). To reflect slower driving on narrow, hilly roads, a discount factor of 0.8 was applied on the speed limit. After processing the OSM data, a directed node-and-link-based road network for the study area was obtained (Figure 2). The large and complex network consists of 15,294 nodes and 37,951 links.



(a) Study area

(b) Lanes per road, terrain & a few downhill routes

(c) Evacuation zones

Figure 2. Map of the study area, road network, evacuation zones and fire hazard severity zones. (a) The whole study area; (b) terrain map and numbers of lanes per road in the evacuation zone; (c) four evacuation zones. (LRA: local responsible area; SRA: state responsible area. VHFHSZ: very high fire hazard severity zone)

3.2.2 Fire Propagation

The Berkeley Hills area borders Tilden Regional Park and mostly falls within the California Department of Forestry and Fire Protection (Cal Fire) Very High Fire Hazard Severity Zones (VHFHSZ, Figure 2). A hypothesized fire is ignited at a transmission tower 0.9 miles northeast of the Berkeley Hills area (coordinate: 37.910399, -122.249261). Fire spread can be modeled by software such as FlamMap or the Wildland-Urban Interface Fire Dynamics Simulator (WFDS) (39,51). However, WUI fire spread is difficult to model due to non-uniform buildings, defensible space, and vegetation. Consequently, data from a nearby and real fire case (1991 Oakland Hills Fire) was borrowed. Both sites are located on the east hillside of the East Bay Hills with similar weather patterns, land topology, vegetation, and housing density. An elliptical fire growth model was fitted to a georeferenced map of the Oakland Hills Fire (Figure 3) (52). The hypothesized fire starts shortly before 11:00 am on a weekend, same as the Oakland Hills Fire. All households are assumed to be at home. These two critical assumptions were used to constitute a "worse-case" scenario. Evacuation orders are sent out 15 minutes after the onset of the fire (reasonable estimate for an urban fire), starting the evacuation. Future work will be necessary to integrate wildfire modeling with traffic simulations to produce more realistic evacuation models.

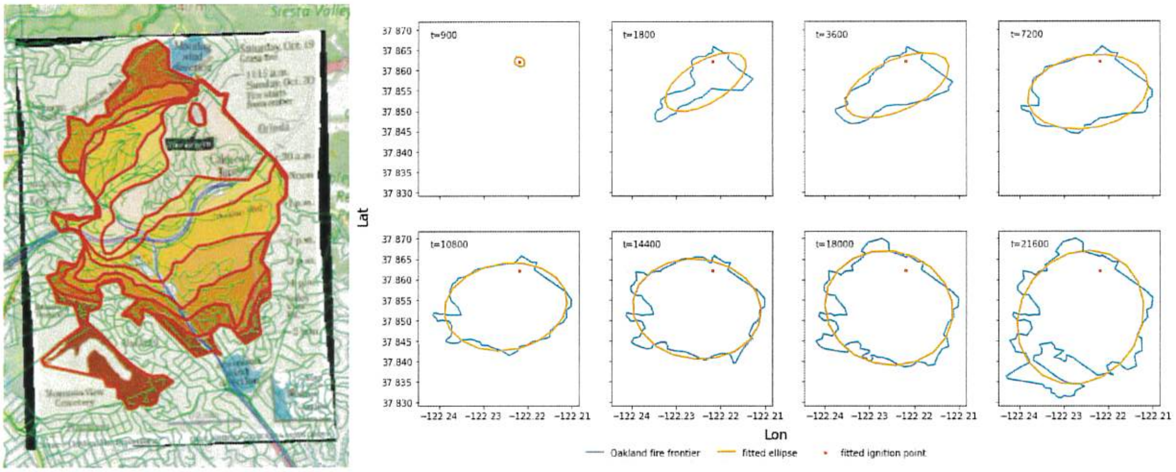


Figure 3. (a) Chronological view of the development of the 1991 Oakland Hills Fire (via Oakland Fire Department from georeferenced image by (52)). (b) Fitting elliptical curves to the observed fire frontier.

3.2.3 Evacuation Zone

Based on fire location, evacuation orders are issued to an assumed area within Berkeley bounded by several major streets (Hearst Avenue on the south, the Shattuck-Sutter-Arlington corridor on the west and the city boundary on the east and north). To add land development realism, a parcel map was obtained for the evacuation area, where each parcel is home to one to five households depending on the land use code (53,54). This accounts for 7,438 households. For simplicity, areas west of Shattuck Avenue (i.e., downtown Berkeley) and south of Hearst Avenue (i.e., University of California, Berkeley campus) are assumed as temporary safe locations. For this study, we generated a random list of origin-destination pairs, where 30%, 30%, 30%, and 10% of the vehicles evacuate to destinations within 1-2 miles, 2-3 miles, 3-4 miles, and 5 or more miles. Our local focus stems from our survey data that found upwards of two-thirds of evacuees remained within their county of origin. The treatment of destination choices is simplistic, as evacuees' destinations could be influenced multiple factors (e.g., availability of shelters, proximity to resources, safety of the destination). Moreover, we did not ask for exact destinations (by address or traffic analysis zone) in our survey and these destinations will require more robust datasets such as mobile phone traces. With this limitation in mind, the results of this study focus on the first half of the evacuation trip (e.g., the time to reach 1 mile away from the evacuation zone or the distance/time exposed to the fire). Time to the destination is not reported, as this does not provide any additional about risk to the evacuee.

3.2.4. Transportation Response Scenarios

We tested a range of wildfire evacuation scenarios, which can be categorized into three groups: hazard (fire speed), evacuation behavior (departure time, towed vehicle demand, transportation mode choice, GPS-enabled rerouting), and policies/responses (phased evacuation, contraflow). For a set of scenario variables, a base case value was chosen for comparison. Details of each scenario are given in Table 2.

Several post-disaster surveys of individuals impacted by California wildfires in 2017 and 2018 were used to define some scenario variables, as discussed in Table 2 (1). For example, mode choice with a focus on vehicles per household was used as a key behavioral parameter. About 41% to 45% of evacuees depending on wildfire used two vehicles to evacuate. Moreover, an additional 9% to 17% of evacuees depending on wildfire used three or more vehicles to evacuate. Even small increases of vehicles on the roadway could significantly increase congestion during a wildfire. For route decision-making, only between 8% and 19% of evacuees depending on fire used GPS navigation. This behavior is particularly interesting given that 78% to 87% of respondents overall had access to in-vehicle or smartphone navigation. This result may be influenced by shorter evacuations during wildfires (about two thirds evacuated within county) and/or evacuees' greater knowledge of route options. Finally, between 6% and 21% of evacuees depending on fire towed items while evacuating (e.g., boats, trailers, or towing personal vehicles using recreational vehicles). Towed items generally increase congestion, take additional space on narrow mountain roads, and reduce traffic throughput. Individuals likely wanted to protect their processions from the fire, leading them to tow items during the evacuation. Additional details and a thorough discussion of these choices and more are provided in (1).

TABLE 2 Descriptions of Scenarios

Category	**Options (Baseline Value Underlined)**	**Description**
Hazard Scenario		
Fire speed	"Slow": Basecase ROS × 0.5 "Normal": 1991 Oakland Hills Fire rate of spread (ROS) "Fast": Basecase ROS × 2	• Wildfire speed depends on fuel type, wind speed, humidity, land topology, etc. • The baseline case uses the fire speed in the 1991 Oakland Hills Fire (Figure 3(b)) • Alternative cases assume the fire speed to be halved (e.g., with proper fuel management and/or firefighting, favorable weather) or doubled (e.g., poor fuel management and/or challenged firefighting, unfavorable weather)
Evacuee Behavior		

Departure time	"Fast": 20 min ± 10 min "Medium": 40 min ± 20 min "Slow": 60 min ± 30 min	• Cal Fire emphasizes the importance preparing and taking swift action in a wildfire ("Ready, Set, Go!") • The planned departure times assumed as a truncated normal distribution (i.e., truncated around the mean at ± one standard deviation) • Vehicles will leave automatically if fire reaches residents' location regardless of the planned departure time • The baseline case assumes the planned departure time to be the medium level *~N(40min, 20min)*, truncated at 20 min and 60 min. • The alternative cases assume shorter or longer departure times
% household towing item	0% 10% (approximated survey) 25%	• Normal vehicles assumed to take 26 ft. on the road, invert of typical jam density (94) • Towed vehicles assumed to take 50 ft. of space (normal vehicle plus a 24 ft. trailer/recreational vehicle) • Survey results indicated that between 6% and 21% of households took towed vehicles during their evacuation • It is assumed each household tows a maximum of one item irrespective of the number of evacuating vehicles • The baseline case assumes 10% households tow an item • The alternative case assumes 0% and 25% households tow an item
# vehicles per household for evacuation	"Low": 1 vehicles/household 44%/43%/13% households leave with 1/2/3 vehicles (approximated survey) "High": 3 vehicles/household	• Survey results indicated that *approximately* 36-45%/41-45%/9-17% of households (depending on wildfire case) evacuate with 1/2/3 vehicles and this is taken as the baseline (12,621 vehicles in total for our case) • Alternative scenarios assume the number of vehicles per household to be one (7,438 vehicles in total) or three (22,358 vehicles in total) • Other forms of transportation (i.e., bus, rail, biking, walking) are converted to single vehicle households for simplicity
% vehicles rerouting	0%	• Survey results indicated that 91% to 93% of the evacuees have smartphones but only

with real time traffic information	15% (approximated survey) 50% 100% 15%, but lost connection to real-time data in 6 minutes 15%, but lost connection to real-time data in 30 minutes 50%, but lost connection to real-time data in 6 minutes 50%, but lost connection to real-time data in 30 minutes	between 8% and 19% of people followed GPS directions during the evacuation (depending on wildfire case study) • It is assumed updated routing information will be available every 10 seconds based on the average link traversal time in the past 20 seconds • Individuals that may reroute without perfect information are not considered • The baseline scenario assumes 15% people follow dynamic updated fastest path while the rest do not update their route • Three alternative scenarios assume different percentages of vehicles that dynamically update their path • Four alternative scenarios assume the connectivity to the real-time routing information is interrupted 10 or 30 minutes after the start of the evacuation (e.g., cell tower losing power)
Policy Scenario		
Phased evacuation time interval	0 min 15 min 30 min 60 min	• Evacuation area is divided into four zones based on distance to the fire origin (Figure 2) • Zone boundaries are all secondary or tertiary roads (i.e., important roads in the residential area) • Baseline case assumes "no phased evacuation": vehicles in four zones have the same mean departure time • Alternative scenarios vary the time interval in the mean departure time of vehicles in each of the four evacuation zones
Contraflow	No contraflow Short-distance contraflow on selected roads (Figure 4) Long-distance contraflow	• Contraflow roads now switch all lanes in the evacuation direction • Baseline case assumes "no contraflow" • Roads were identified based on long traffic queues from the baseline simulation and local knowledge of primary routes in the area • Alternative scenarios assume a short-distance or a long-distance contraflow

3.3. Limitations

In addition to the assumptions described in the prior section, we note several key limitations here. First, the surveys exhibit self-selection bias as they were opt-in. We attempted to reduce this bias through a wide distribution across multiple agencies and news sources. Participants also skewed wealthier with more vehicles, due to the online distribution, and the sample sizes for the surveys were small. Additional survey limitations are described in further details in (1). The survey data also has measurement error, leading us to choose approximate values for the model. Finally, we note that we used survey data from other locations to develop the scenarios for the Berkeley Hills, as a major fire has not occurred recently in the Berkeley Hills. Despite this possible mismatch of traffic, social, climate, and cultural factors, the surveys and our study area were similar based on fire risk (WUI zones), housing type (mostly single-family residences) and income level (high income level). Future work is needed to apply modeling across more geographies and collect more survey data to increase generalizability.

There are limitations regarding the network representations. For example, even though the city recommends off-street parking on a red flag day, the compliance is not guaranteed. This is a major issue hindering evacuation, as the road network in the study area (as well as many other high-risk sites beyond this study) is quite windy and narrow. Also, there are critical intersections where left-turns block other movements or where two traffic streams merge. Evacuation efficiency could be significantly improved if these critical intersections can be correctly managed (e.g., forming undisrupted evacuation routes (55)). However, such strategies usually require optimization techniques to be formulated and are not included in this study. We also note that our network does not consider the impacts of vehicle breakdowns or emergency vehicles (which need to travel uphill towards the fire). However, since contraflow is not instituted on all uphill routes, emergency vehicles would find alternative roads to access the fire or those in needs. The network analysis also assumes that most evacuees will not travel far distances, which is supported by the survey data. However, mass evacuations over 100,000 people may require a better understanding of destinations and shelter types (along with the suitability of these locations) for the simulation.

Regarding traffic models, due to data availability and coding efficiency considerations, sub-link behaviors in the model (e.g., lane-changing aggressive drivers) were not included. The node model is not detailed enough to investigate within-intersection events. We remove signaling for simplicity, since so few nodes in the study area are signalized. The "fastest" path assumption is limited as evacuees likely do not have full knowledge of congestion, choosing detours to circumvent congestion. Research has also shown that other factors impact routing beyond shortest path (11,56). Pedestrian-vehicle interactions are not considered, evacuees are assumed to leave via a vehicle (overestimating congestion), and individuals rerouting without perfect information are not considered.

For the scenarios, interactions of different strategies are not considered due to the already large numbers of studied variables, despite possible correlated effects (57). Incidents such as fallen trees blocking the roads are not considered. A shelter-in-place option is not considered. We assume 100% of residents are home and 100% of evacuees will leave even though research has shown compliance of mandatory evacuation orders around 90% (11). This oversimplification is chosen to model both a disadvantageous scenario for congestion, but also an ideal outcome (in terms of compliance to mandatory evacuation orders) for public safety agencies. We also note that we oversimplify the evacuation process (one trip per household, with no trip-chaining). Past research has demonstrated that evacuees may take multiple stops before reaching the destination. For example, (6) found that people make 1.1 intermediate stops on average based on post-wildfire surveys in Haifa, Israel. Families with children make more intermediate stops, at 1.5 on average. (58) also argued that trip-chaining helped explain certain travel behaviors (e.g., evacuating towards the fire area), which avoids overly optimistic travel time predictions. In the simulation case study presented in this paper, trip chains are not considered (e.g., child pickup or helping carless individuals). However, the considered scenario, namely a weekend morning when all residents are at home, is likely to imply an equally disadvantageous demand level. First, additional trips such as child pickup or return home from work are usually happening during work hours, which coincides with the time that most residents are away from home in the residential neighborhood. Second, during wildfire events, there are usually orders in place that prevents people from entering the fire zone.

Apart from excluding trip-chaining, we also simplify the model by not including surrounding vehicles (i.e., background traffic), multiple pre-evacuation trips by households, or post-evacuation trips. We also did not consider shadow evacuations (i.e., evacuation of individuals who did not receive a mandatory evacuation order), which is a limitation. More data is needed to determine the extent of shadow evacuations, especially in cases where evacuation orders are delivered effectively and on-time. We also note that specific vulnerable population evacuations were not considered. For instance, in zip code area 94708, which covers most of the evacuation area, there are 2,850 Old-Age, Survivors, and Disability Insurance (OASDI) beneficiaries (59). Agencies with local knowledge should make these populations a priority. The destination choice in the simulation is based on the notion that most wildfire evacuations are short-distance trips. Destinations for each simulated vehicle are randomly sampled according to the trip distance distribution obtained from the survey. Three random variables are used, and results indicate that stochasticity in destination locations only have minor impacts on the results. Future work is necessary to also consider how shelter locations could be incorporated into the modeling.

Most critically, simulations are not perfect representatives of real-life behavior. The number of factors, random events, and governmental decisions would be nearly impossible to model. We acknowledge that our simulation, while incorporating past behavioral data, could be continuously improved with greater realism. This might also include how demographic characteristics impact the decision to evacuate or stay/defend (see (6–8,11,13)). Though, most of these studies have found that risk perceptions, not demographics, are better predictors of choice. Regardless, integrating discrete choice analyses with this simulation framework is a logical next step. Finally, the simulation framework is not straightforward for agencies to use directly due to the lack of an interactive dashboard. Efforts are being made to make the code and data open-sourced, as discussed in Section 3.4. Our aim is to produce a workable simulation model that is a stepping stone for more behaviorally driven research.

3.4 Simulation Reproducibility

Reproducibility is defined as the ability to confirm the results of a previous experiment by means of another similar experiment (60), and it is a crucial criterion in ensuring the credibility of scientific results. (60) categorized reproducibility into four levels, from being able to reproduce the results using the same data and model, to reproducing the results based on general descriptions of the model specifications. The model presented in this paper is based on computer simulations. Efforts to ensure reproducibility include:

1. **Stating model specifications and key assumptions in detail in the methodology section (Section 3).** Based on these specifications, the results can be verified and reproduced in other simulation software;
2. **Conducting repeated experiments with random seeds as shown in the results section (Section 4).** Despite the minor differences in each random experiment, the magnitude and overall conclusions of the results were largely unchanged;
3. **Providing open-sourced simulation code.** To ensure that the results and conclusions are reproducible by future researchers, the simulation code is open-sourced, and data inputs are available upon request.

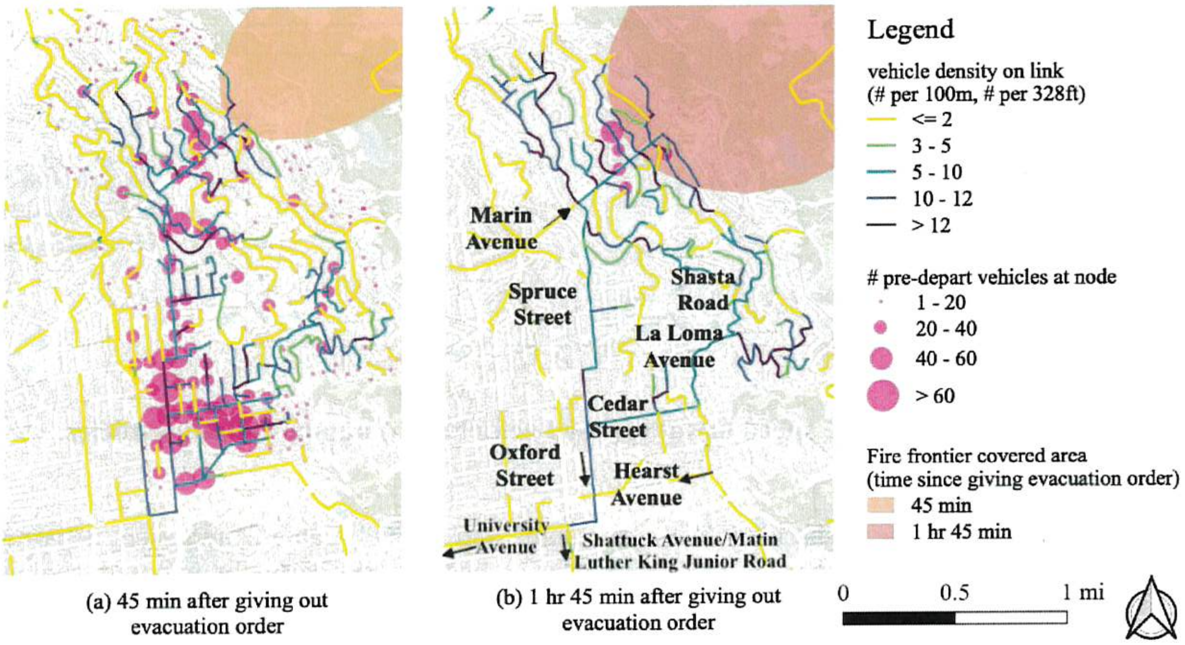
4. RESULTS

We begin with presenting the baseline case for the wildfire simulation. Figure 4 shows the simulated congestion status at two specific time steps for the baseline case. Each road link is colored by vehicle density, while each road node is represented by pre-departed vehicles. Figure 4(a) shows results at 45 minutes since giving out the evacuation order. The traffic is visibly heavier than Figure 4(b), which is at 1 hour and 45 minutes after giving out the evacuation order. We note that the most congested roads are often branch roads merging into key routes (e.g., the roads leading to Marin Avenue).

For each scenario shown in Table 2, the alternatives are compared against the base scenario, while fixing all other strategies to their respective baseline values (underlined values in Table 2). Three random repetitions are conducted to reduce the influence of random variabilities on the outcomes. Two evacuation related metrics are shown in detail:

- **Safe Vehicles:** Total number of vehicles that have reached at least one mile away from the evacuation zone;
    - Designates vehicles reaching safe location;
    - Can derive evacuation time estimates;
- **Exposed Vehicles:** Number of vehicles within in the fire frontier;
    - Identifies vehicles overtaken by the fire (i.e., potential risk or danger);
    - Does not necessarily signify fatalities.

The metrics are plotted over time for the baseline and each comparison scenario. Other summary statistics are given in Table 3, including time of exposed vehicles and average distance from the fire frontier.



(a) 45 min after giving out evacuation order

(b) 1 hr 45 min after giving out evacuation order

Figure 4. Results from the spatial-queue-based traffic simulation, including the vehicle density on each road link and number of pre-depart vehicles (either because of the delay in departure or being blocked from the first link). (a) Results at 45 minutes since the evacuation order is given out (1 hour since the ignition of the fire); (b) Results at 1 hour and 45 minutes since the evacuation order is given out (2 hours since the ignition of the fire);

4.1 Fire Speed

We first vary the fire speed to reflect potential changes in weather conditions, firefighting, and/or fuel management. In the baseline case, fire overtook the first vehicle at 14 minutes after the evacuation order was given (Figure 5(a)). The number of exposed vehicles reached its peak of 782 vehicles at 2.3 hours. Compared to the baseline, this metric decreases by 56% if the fire speed can be reduced to half (e.g., through effective firefighting, fuel management, weather, etc.) or increases by 55% if the fire speed doubles. Figure 5(b) shows safe vehicles and the associated ETEs. Fire speed only minimally influences ETEs since most vehicles depart before the fire reaches their households in all scenarios. Additional work will need to identify how departure time and mobilization time is influenced by fire speed, especially given the role of speed in challenging evacuations in past wildfires (1).

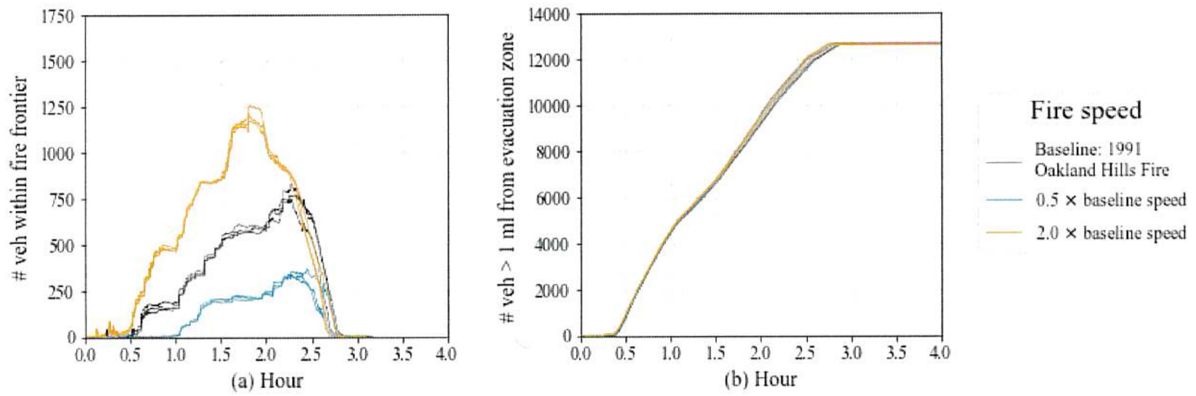


Figure 5. The impact of fire speed on (a) exposed vehicles; (b) number of safe vehicles.

4.2. Departure Timing

The three departure time scenarios (“fast”, “medium” and “slow”, Table 2) represent departure times after receiving the evacuation order. Scenarios perform similarly for exposed vehicles (Figure 6(a)), possibly due to relatively close means for all three cases (20, 40 and 60 minutes). The number of exposed vehicles in the “fast” departure scenario grows ahead of the other two cases due to earlier buildup of queues on Marin Avenue (a key local route).

Figure 6(b) shows both the cumulative number of vehicles that started the evacuation (dashed line) and safe vehicles. We note that the dashed line for the cumulative distribution function (CDF) does not follow a truncated normal function, since some vehicles cannot enter fully saturated links. The “fast” case is the most efficient in ETEs, showing the benefit in early departure. However, the magnitude of the time savings of a 20-minute earlier departure is minimal. Compared with Section 4.4 (phased evacuation), more gradual departure times (without staggering the departure spatially) alleviate less congestion.

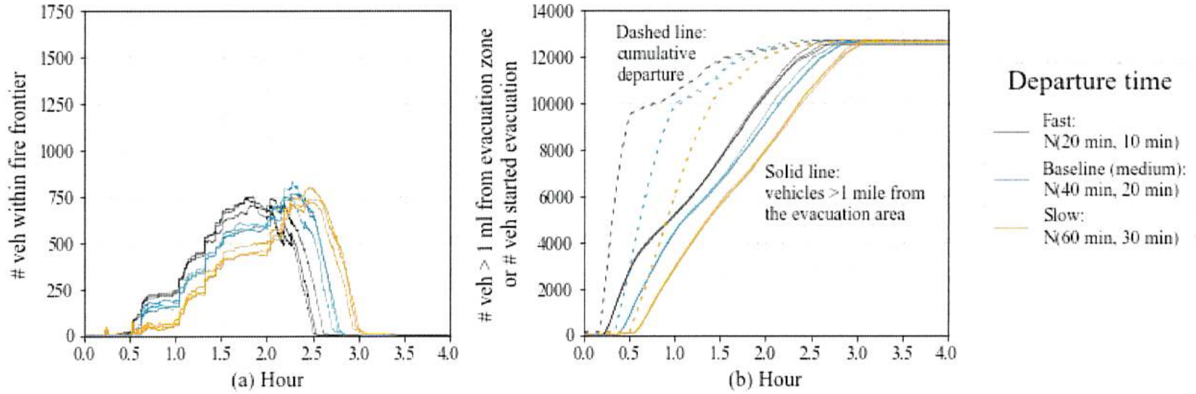


Figure 6. The impact of departure delays on (a) exposed vehicles; (b) safe vehicles.

4.3 Towing

Normal vehicles are assumed to take 26 ft of space on road, the invert of typical jam density (94) with towed items taking an additional 24 ft (approximate trailer length). Assuming the percentage of households towing items is 0% or 25%, the simulation results in -5% and 8% changes in the total vehicle length compared to the baseline

(10% households take towing items). The maximum number of exposed vehicles changed by -3% and 5% compared to the baseline, while the ETEs changed by -7 minutes and +4.2 minutes, a rather small change compared to other scenarios.

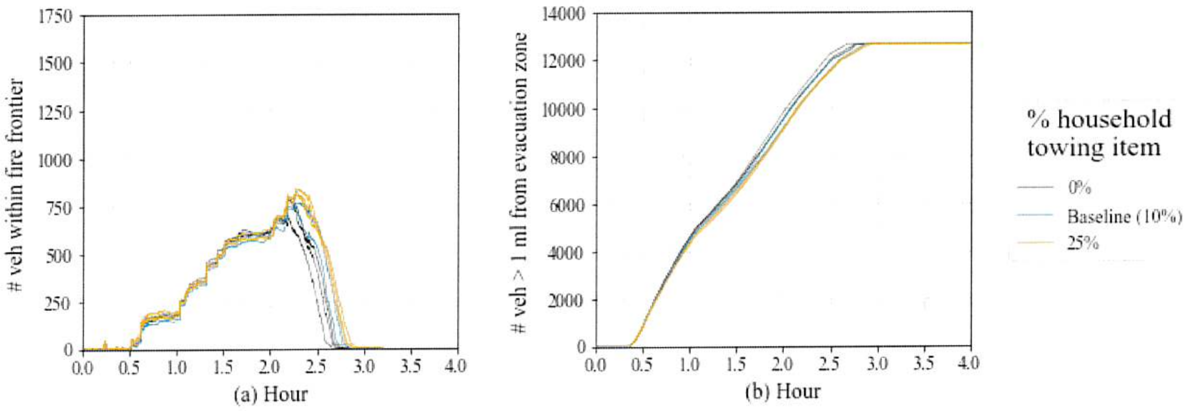


Figure 7. The impact of towing items on (a) exposed vehicles; (b) safe vehicles.

4.4 Transportation Mode Split

Evacuating households often use multiple vehicles to take belongings, family members, and pets or to remove the vehicle from danger (61), leading to more congestion. Our baseline case sets the household vehicles for evacuation according to the survey (about 1.7 per household), resulting in 782 exposed vehicles (about 6% of the total demand) and an ETE of about 3 hours. If all households evacuate with only one vehicle, the maximum number of exposed vehicles falls to 245 (about 3% of the total demand) and the ETE is cut to 1.9 hours. If all households evacuate with three vehicles, exposed vehicles reach 2,497 (11% of the total demand). Only 19,953 vehicles can reach the safe area in 4 hours (89% of the total demand in this scenario).

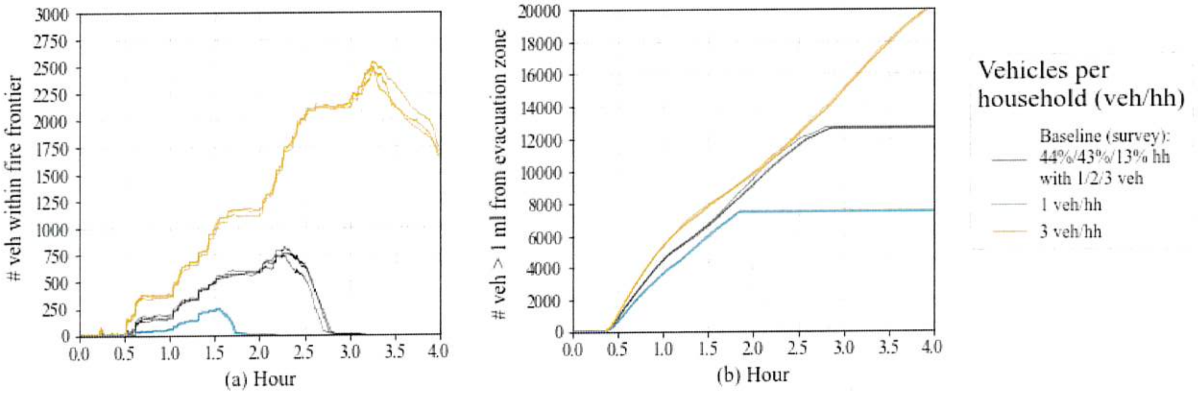


Figure 8. The impact of number of vehicles per household on (a) exposed vehicles; (b) safe vehicles. Note the scales are different.

4.5 Real-Time Traffic Information for Rerouting

Rerouting can theoretically relieve congestion by distributing the traffic to other roads. The black lines in Figure 9(a) presents baseline results with 15% rerouting (similar to the survey). The orange, blue and green curves correspond to scenarios where 0% (no information), 50% (strong access to rerouting information), and 100% (theoretically equivalent to automated vehicles [AVs]) of the drivers reroute. Compared to baseline, the exposed vehicles change by +20%, -51% and -

89%, respectively. Figure 9(b) shows that the alternative scenarios can also reduce the ETEs to 3.2, 2.1 and 1.2 hours compared to 2.9 hours in the baseline case.

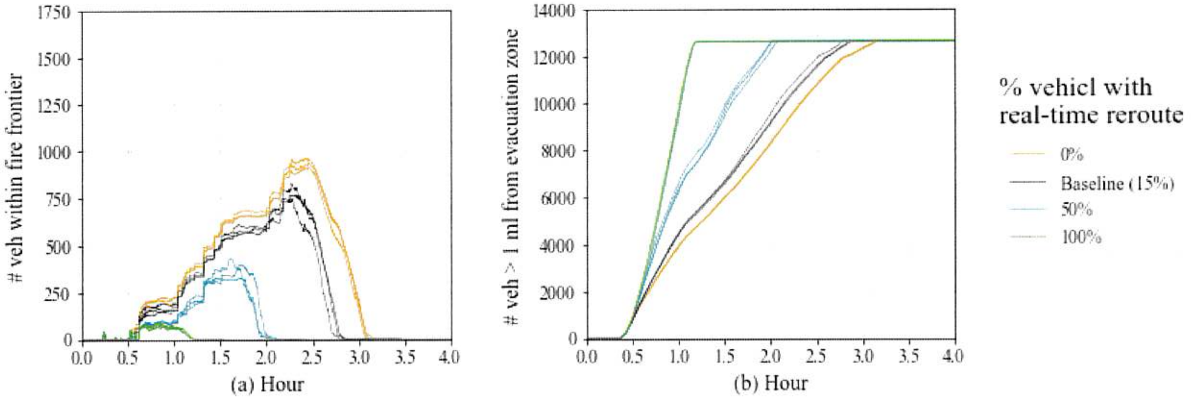


Figure 9. The impact of vehicle rerouting on (a) exposed vehicles; (b) safe vehicles.

However, rerouting may not be a safe option due to road closures or connectivity challenges, as was the case of the Camp Fire (62). We further explored this scenario in the simulation and the results are shown Figure 10. In Figure 10, results of two levels of real-time routing participation rate (15% and 50%) and three levels of interruption timing (no interruption, interrupt at 30 minutes and 6 minutes) are plotted. In the base case (black curves), 15% of vehicles follow real-time routing information, and such information is available throughout the evacuation process. Comparatively, the orange and red curves show the results when the connection to the real-time information is interrupted at 30 minutes or 6 minutes. Unless the connectivity is lost at a very early stage, the influence on evacuation efficiency is minimal (orange curve almost coincides with the base curve). The reasoning is that the total number of rerouting vehicles (15%) is relatively small. For these vehicles, many are routed away from the congested roads at the beginning and are not adjusted significantly during the evacuation. This can be seen in Figure 11(a), where the thickness of the lines indicates the numbers of vehicles using each link throughout the entire simulation and the color indicates the percentages of rerouting vehicles. We note that the percentage of rerouting vehicles on the congested roads (thick lines) is lower (less than 5%) than the scenario average of 15% rerouting. As a result, interrupting rerouting after congestion starts to form will not alleviate or worsen congestion significantly. However, if rerouting is interrupted at the beginning of the simulation (e.g., the red curve in Figure 10), the vehicles with rerouting capabilities are not able to avoid the congestion, since delays have not started to form when they are planning their routes. The results of a loss of connectivity early in the evacuation are very similar to results without rerouting (orange curve in Figure 9). For higher usage of real-time rerouting (50% of vehicles using real-time rerouting, blue/green/purple curves in Figure 10), the impact of losing such information is clearer. As shown in Table 3, if the connection to the real-time information is lost at 30 minutes while 50% of the evacuees are trying to follow it for routing, the number of exposed vehicles increases by almost 100 compared to the no interruption case, while the total exposed time (vehicle-hours) increases by over 50%. Figure 11(b) also illustrates this. Since evacuation efficiency is dominated by the congestion on a few routes, significant improvements could be made if vehicles on these congested routes could have used real-time rerouting to seek an alternative route.

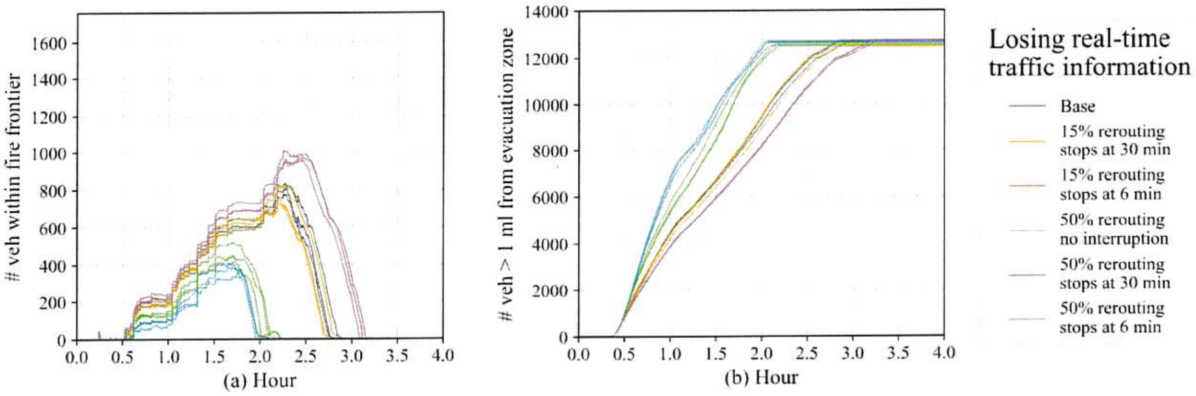


Figure 10. The impact of interrupting real-time routing at different stages of the evacuation.

(a) 10% rerouting, stops at 30 min

(b) 50% rerouting, stops at 30 min

Figure 11. Total numbers of vehicles using each link (thickness) and percentages of vehicles with real-time rerouting on each link (color scale). (a) 15% of all evacuees follow real-time traffic information; (b) 50% of all evacuees follow real-time traffic information.

4.6 Phased Evacuation

Phased evacuations often improve congestion by reducing the maximum instantaneous traffic load and increases overall safety by prioritizing residents in greater danger (63). We tested phasing by altering time intervals between the mean departure time of different evacuation zones (Figure 12). Figure 12(a) shows exposed vehicles for different phased evacuation intervals. By giving a 15-minute priority to each of the evacuation zones closer to the fire (blue curve), exposed vehicles reduce by 78%. If the phase interval increases to 30 minutes (green curve), exposed vehicles reduce by 94%. However, if the phase interval becomes too large (e.g., 60 minutes, orange curve), some vehicles may leave too late and be overcome by the fire, increasing exposed vehicles slightly compared to the 30-minute case. Figure 12(b) shows safe vehicles differ minimal from baseline for phase intervals of 15 minutes and 30 minutes. However, when the phase interval becomes 60 minutes, the network is underutilized (characterized by flat lines).

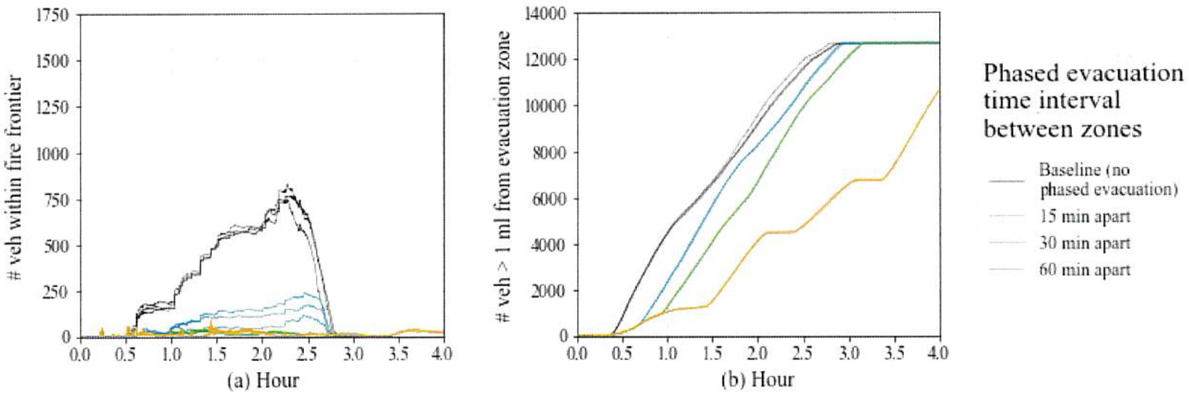


Figure 12. The impact of phased evacuation on (a) exposed vehicles; (b) safe vehicles.

4.7 Contraflow

In this study, the locations of contraflow were identified based on inspecting the bottlenecks in Figure 4, centerline markings, and local knowledge of downhill routes as:

For short-distance contraflow, resources are assumed to be limited and the strategy could only be implemented along the key egress routes to slightly beyond the evacuation boundary:

- West side downhill routes (3.7 miles long, extending 0.5 mile outside of the evacuation zone): Marin Avenue → Spruce Street → Oxford Street; and
- East side downhill routes (1.9 miles long): Shasta Road → Glendale Avenue → La Loma Avenue → Cedar Street → Euclid Avenue → Le Conte Avenue → Hearst Avenue (→ join the westside contraflow routes at Oxford Street).

When there are sufficient personnel and time, contraflow roads can be extended to local highways. In this scenario, the contraflow strategies are also implemented following roads:

- Shattuck Avenue and Martin Luther King Junior Way, from University Avenue till CA-24 (2.7 miles).
- University Avenue, from Shattuck Avenue till I-80 (2.2 miles).

Figure 13(a) shows a reduction of 53% of exposed vehicles after implementing contraflow to the evacuation zone boundary. In the extended contraflow scenario, the number of exposed vehicles reduced by 73% compared to the baseline. In Figure 13(b), the number of safe vehicles and ETE does not change substantially when the evacuation lanes terminate close to the evacuation boundary. In fact, this is in accordance with the characteristics of contraflow: it helps absorb more vehicles from branch roads to the contraflow lanes, thus making it faster for the vehicles to outrun the fire. However, in an urban setting, the downstream (sink) capacity is still limited by the end of the contraflow roads, leading to vehicle queues downstream of the contraflow roads. By extending the contraflow lanes to a further distance away from the evacuation zone, it is possible to reduce the queue spillback into the evacuation zone, making it faster for vehicles to leave the dangerous area.

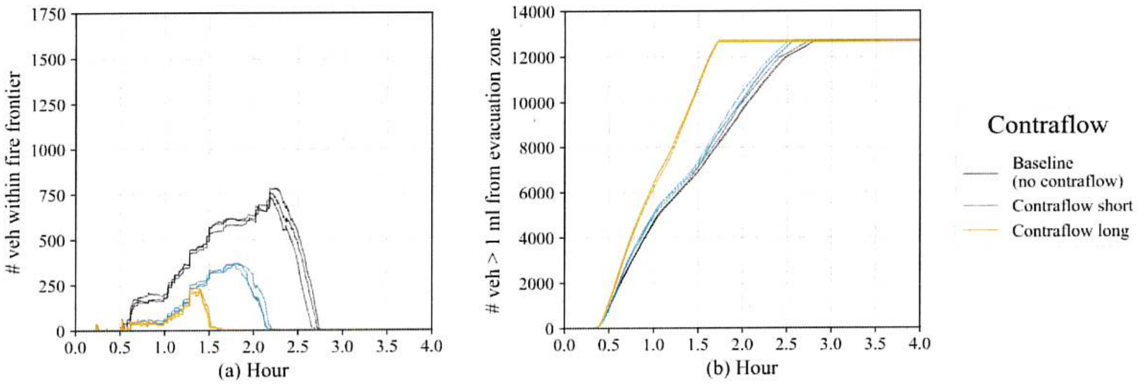


Figure 13. The impact of contraflow on (a) exposed vehicles; (b) safe vehicles.

4.8 Summary of Findings

Four summary statistics are given in Table 3 for comparison: 1) exposed vehicles; 2) ETE; 3) amount of time exposed vehicles were in the fire frontier; and 4) average distance from fire. The time for all vehicles to complete the evacuation is not shown, as the evacuation destinations were picked at random and sometimes constitute long trip times.

Based on summary statistics in Table 3, phased evacuations with 30-minute departure time interval, >50% vehicle rerouting, personal vehicle reduction (1 vehicle per household) and instituting contraflow beyond the evacuation zone boundaries are the most effective strategies. These strategies can greatly reduce the load of the traffic temporally (phased evacuations), spatially (rerouting and contraflow), and overall (personal vehicle reduction). Each strategy has limitations: phased evacuations require strict adherence to mandatory orders, vehicle rerouting requires real-time information from power and cell sources and quick detection of road closures, personal vehicle reduction requires significant education and a willingness to give up an expensive asset, and contraflow requires planning efforts and is labor-intensive during its execution.

Some strategies (e.g., slowing fire speed, phased evacuation with less time intervals between zones, selective contraflow) have less impact on ETEs but still lead to moderate reductions in exposed vehicles. Reducing fire speed provides more time for slower households to leave. We found that rapid phasing, compared to more drawn-out phasing, overloads the network too quickly and is not as effective as other phasing intervals. Contraflow over a short length also removes individuals quickly from the fire area, but downstream congestion still leads to high ETEs. Several strategies, such as changing towing behavior and speeding up departure times, lead to minimal reductions in both exposed vehicles and ETEs. The worst case among all scenarios studied is to evacuate with three vehicles per household. This represents the highest evacuation demand on a network with limited capacity and is detrimental in all metrics evaluated.

The above simulation results are based on the series of scenarios and assumptions as stated in Sections 3.2 and 3.3. In reality, situations that deviate from these assumptions might happen and lead to changes in the outcomes. For example, depending on the time and day of the incident, there may be less people at home compared to the current assumption. This will reduce the evacuation demand, effectively leading to less challenging evacuation situations similar to the effect of vehicle reduction. Also, it has been suggested that people may make multiple trips during the evacuation (6,58). This has the potential to increase the overall ETE and conflicts at intersections, for example. Other factors that will affect evacuation outcomes include shadow evacuations, the presence of pedestrians sharing the road network, vehicle breakdowns, emergency vehicles traveling in the opposite direction, transportation of vulnerable populations, and public transit usage. In addition, the resilience and operations of the infrastructure may also impact the overall evacuation efficiency. For instance, signals that are not optimized may create long queues of traffic backing up (64). However, as the signalized intersections in the study area are mostly out of the evacuation zone, it may not significantly affect evacuation metrics, such as the fire exposure time. Realistically, multiple disadvantageous scenarios may happen at the same time, such as a fast-moving fire that damages the communication and navigation infrastructure, causing difficulties in coordinating contraflow operations between emergency personnel and/or evacuee challenges in accessing real-time routing information.

TABLE 3. Summary of Evacuation Efficiency Metrics under Different Strategy Scenarios.

	Evacuation Efficiency Metrics					
	Exposed Vehicles		**Evacuation Time Estimate (ETE)**		**Total Time of Exposed Vehicles**	**Distance from Fire**
	Max # veh in fire frontier at the same time (veh);	% change from baseline	Time (hrs), all vehicles reach safety, 1 ml from evac zone;	% change from baseline	Total veh-hours fire frontier (veh-hrs)	Min. average distance to the fire frontier (miles)
Baseline						
Baseline	782	-	2.9	-	954	0.6
Fire speed						
×0.5 (slower)	342	-56%	2.8	-1%	350	0.8
×2 (faster)	1,209	+55%	2.8	-2%	1,569	0.5
Departure time						
Less delay	729	-7%	2.7	-5%	910	0.4
More delay	747	-4%	3.1	+7%	906	0.6
% towed vehicles						
0%	757	-3%	2.8	-4%	885	0.7
25%	821	+5%	3.1	+2%	906	0.6

# vehicles per household for evacuation						
1	245	-69%	1.8	-36%	129	0.9
3	2,497	+219%	>4	>+40%	5,057	0.4
% vehicles rerouting with real-time traffic information						
0%	943	+20%	3.2	+11%	1,320	0.6
50%	381	-51%	2.1	-28%	279	0.8
100%	86	-89%	1.2	-58%	35	0.7
15%, stop at 6 min	979	+25%	3.1	+7%	1,430	0.6
15% stop at 30 min	771	-1%	2.8	-3%	974	0.6
50%, stop at 6 min	979	+25%	3.1	+7%	1,430	0.6
50%, stop at 30 min	474	-39%	2.1	-28%	411	0.8
Phased evacuation time difference between bands						
15 min	173	-78%	2.9	+2%	188	0.8
30 min	49	-94%	3.2	+10%	35	0.8
60 min	80	-90%	>4	>+40%	40	0.7
Contraflow						
Short contraflow	367	-53%	2.6	-10%	310	0.8
Long contraflow	209	-73%	1.7	-41%	84	0.9

5. POLICY RECOMMENDATIONS

The modeling results point to clear opportunities for emergency management and transportation agencies to reduce wildfire evacuee risk and improve ETEs. In Table 4, we present each of the transportation responses, their priority, and possible recommendations for agencies to pursue. We note that many strategies will require careful planning and substantive communication with residents. Indeed, informational and educational campaigns (not infrastructure or operational changes) that attempt to nudge behavior may be the most cost-effective strategy to improve evacuation outcomes.

TABLE 4: Policy Recommendations for Transportation and Hazard Responses and Strategies

Transportation/ Hazard Response	**Priority**
1. Slowing Fire Speed	Moderately Recommended

Description

Slowing fire speed will reduce the number of vehicles in the fire frontier and allow for longer mobilization times, especially for vulnerable populations who might need more time to evacuate. However, slowing fire speed requires very quick and rapid response to the hazard or longer-term fuel management strategies (e.g., fuel breaks), which may not be feasible for some jurisdictions. Moreover, the typology, land development, and weather conditions may make fire suppression nearly impossible, placing firefighters or aircrafts at risk.

Recommendations for Emergency Management and Transportation Agencies

- Manage fuels and create fire breaks by reducing highly flammable vegetation in high-risk areas (e.g., near powerlines) and along roadways
- Develop rapid detection systems for wildfires (e.g., cameras, sensors, physical lookouts, crowdsourced information, drones)
- Work with homeowners and landowners through education, funding, and enforcement to create defensible space, fire resistant structures, and backup water storage systems

Feasibility

Fire spread depends on the weather, topology, and fuel. Studies have shown that fuel management such as Fuel Reduction Burning (FRB) can effectively slow down the rate of head fire spread (65). Also, structures that are separated by sufficient distances or have defensible space around them can help stop or slow down fire (66). Smart technologies are also maturing and have been adopted in practice, such as using fire cameras combined with Artificial Intelligence (AI) to rapidly detect fire and smoke at early stage (67). The benefits of slowing fire spread are clear, but actions will require substantial effort by agencies and residents. Agencies should work on community preparedness and prescribed burning. Residents should conduct actions for the residence (e.g., clean gutters, use fire resistant roofing and exterior in high-risk areas). Economically, however, this can be difficult for low-income communities (e.g., metal roofing can be 5-10 times more expensive than asphalt roofing materials), indicating equity challenges.

2. Reducing Departure Delays	Moderately Recommended

Description

Reducing the departure time lag between receiving a mandatory evacuation order and evacuating can help remove at-risk people more quickly. However, this strategy alone is not enough to sufficiently reduce evacuation risk. Moreover, some individuals, such as individuals with a physical disability, may need extra assistance and additional time to evacuate.

Recommendations for Emergency Management and Transportation Agencies

- Issue mandatory evacuation orders as quickly as possible to ensure enough time for individuals to mobilize and leave, especially individuals with access and functional needs (AFN)
- Encourage residents to create go-bags that speed up the mobilization process
- Include in mandatory evacuation orders an approximate amount of time they should spend mobilizing that is long enough to prepare but also short enough to evacuate individuals quickly

Feasibility

Reduction in departure delay can be achieved through improving pre-event preparedness and giving evacuation orders in a timely and clear manner. Cal Fire and local agencies have made efforts in improving this preparedness with the public-facing website readyforwildfire.org that disseminates "Ready, Set and Go" information (68). For alert systems, most local areas are gradually adopting state-of-the-art software, such as Code Red, and/or updating their Wireless Emergency Alert (WEA) system. However, issues remain in disseminating information quickly, in multiple languages, with adequate direction, and to enough people (1). Reducing evacuation delay is attainable, but based on recent experience, a robust communication system (along with correct decision-making from officials) is needed.

3. Reducing the Amount of Towing	Minimally Recommended

Description

Additional mobile assets (e.g., trailers, boats, motorhomes) create more demand, but this increase is minimal to moderate. A reduction in towing leads to some gains across evacuation metrics. However, mobile assets tend to be expensive, making them a higher priority for protection.

Recommendations for Emergency Management and Transportation Agencies

- Encourage residents in high-risk areas with mobile assets to gain wildfire (e.g., disaster) insurance
- Suggest to residents to hook up and prepare mobile assets ahead of potential fire danger to reduce mobilization time
- Develop plans for parking areas outside of potential evacuation zones for residents to take mobile assets during high fire danger weather (i.e., pre-disaster trip-making)

Feasibility

There is currently little information on agency regulation or recommendations regarding towing vehicles, so its current feasibility is hard to assess. Based on the Federal Highway Administration (FHWA) highway statistics of 2019, the ratio of trailers versus automobiles (all privately owned) in the fire-prone states California, Nevada, Oregon, and Washington were 0.16, 0.18, 0.22 and 0.20, respectively (69). The values are within range of the simulation inputs (0-25%) in this study. Trailer usage in places with large farm animals may be higher and planning for their safe evacuation might be more crucial.

4. Reducing Number of Evacuating Vehicles	Highly Recommended

Description

The travel demand from multiple vehicle households greatly increases exposed vehicles and ETEs. By reducing the number of vehicles taken by households, congestion will be greatly diminished and allow evacuees to reach their destinations more quickly. Reducing vehicles is highly recommended for all jurisdictions but this strategy will require significant and proactive educational campaigns.

Recommendations for Emergency Management and Transportation Agencies

- Recommend to residents to take as few vehicles as possible (i.e., enough to transport people and key belongings) through an educational and informational campaign
- Suggest to resident to pre-pack vehicle(s) in advance such that space is used efficiently in vehicles
- Encourage evacuees taking more than one vehicle to provide their extra space to carless individuals and other vulnerable populations to improve equitable outcomes
- Develop an equitable insurance framework for protecting vehicles of residents in high-risk fire areas
- Develop plans for parking areas outside of potential evacuation zones for residents to take additional vehicle during high fire danger weather (i.e., pre-disaster trip-making)

Feasibility

Based on data from 1990-2010, the WUI is the fastest growing land use type in the contiguous United States (70). With mostly single-family houses in the WUI (71), private vehicle are the primary mode of transport in such areas. In the Berkeley Hills area (most of which belongs to zip code 94708), the average household size is 2.3, but there are nearly 2 vehicles per household on average. As a result, carpooling would be considered less attractive given the high car-ownership. Israel, for example, having lower car ownership than the United States, was reported to use 0.89 vehicles per household for evacuation (6). The benefits of vehicle reduction during evacuations are well understood in the literature, and there is already some development of education campaign by agencies. For example, Marin County in California advocates on its website that "every seat should be filled" and that evacuees should "assist elderly or disabled neighbors" and "carpool with neighbors to reduce traffic" (72,73). (57) noted the difficulty in vehicle reduction and compared this to the "prisoner's dilemma", where residents would have to forsake personal properties (vehicles and belongings that could not be taken) for the overall benefit of reduction in traffic. One important possibility is that auto insurance could help to reduce the financial loss of vehicles if they are left at the residence. Some auto insurance policies cover wildfire damage but not all people can afford this comprehensive coverage. In terms of parking capacity in the study area, there are nearly 1,400 off-street parking spots owned and operated by the City of Berkeley, including three garages and two surface parking lots in Downtown Berkeley, South Berkeley, and the Elmwood district (74). There are also over 1,400 parking spaces at the North Berkeley and Ashby stations for Bay Area Rapid Transit (BART) (75). In addition, the above totals do not count for parking owned by companies, employers, or private operators. Other parking structures, such as those on the nearby University of California, Berkeley campus, can also provide additional space for the pre-evacuation of vehicles. For other cities, a similar crude validation can be used to estimate the feasibility of a pre-evacuation parking strategy.

5. Increasing GPS-Based Rerouting	Highly Recommended

Description

Higher rates of rerouting led to significant reductions in exposed vehicles and ETEs. Even smaller percentages of rerouting (15%) were far more effective than other potential transportation strategies. Despite these benefits, a rerouting strategy will have to ensure that GPS-guided directions are available, accurate, and followed by evacuees.

Recommendations for Emergency Management and Transportation Agencies

- Partner with GPS mapping services (e.g., Google Maps, Apple Maps, Waze) and auto manufacturers with GPS guidance to ensure that systems with be operational in a disaster
- Update mapping services through official or crowdsourced information of blocked routes (i.e., downed powerlines, trees) and current fire location
- Work with and require utilities to have backup generators for key communication services (e.g., high-speed mobile Internet) to ensure GPS directions are available
- Produce pre-disaster information related to GPS guidance to evacuees and encourage usage of services, even for short evacuations
- Encourage services to default applications to reroute in an evacuation, rather than remain on the current route
- Consider future integration of wildfire evacuation information to automated vehicles (AVs)
- In the long-term, develop vehicle-to-everything (V2X) technologies that can exchange information and compute real-time routes without relying on vulnerable communication infrastructures (e.g., cell towers)

Feasibility

Real-time rerouting is an effective strategy in all scenarios studied in the simulation. However, its feasibility is dampened by several challenges. First, real-time rerouting services are mostly provided by private companies. While many have shown strong willingness to assist (e.g., Google hazard map showing real-time closures), companies have yet to develop robust partnerships with agencies. Second, GPS systems need to be paired with transmission infrastructure (e.g., cell towers) to communicate with the central server about current positions. However, cell towers and other communication infrastructures have been susceptible to power outages, losses of backhaul fibers, and structure damages from wildfires (76). In 2020, California Public Utilities Commission issued a new decision for major wireless providers to have 72 hours of backup power and build new communication resiliency and emergency operations plans (77). Other opportunities for ensuring communication include the use of short-range equipment to act as temporary stations (e.g., using drones to relay wireless signals in (78)). However, these innovations are still largely conceptual. Finally, people may not choose real-time routing guidance during an evacuation, opting instead for routes that are shorter, have less fire danger, and high-quality pavement conditions (12). Altogether, real-time routing requires improvements to enhance V2G (vehicle to grid) infrastructure and V2V (vehicle to vehicle) infrastructure to support more secure and robust communication to make rerouting feasible (79–82).

6. Phasing Evacuations	Highly Recommended

Description

Depending on the phasing time difference (and size of phased zones), a phased evacuation strategy can be effective in improving evacuation outcomes on its own. However, phasing requires significant pre-planning activity and active communication with residents before and during the evacuation, making it difficult to implement. Moreover, the characteristics of the wildfire may make a phased evacuation impossible, as the fire may overcome non-evacuated zones.

Recommendations for Emergency Management and Transportation Agencies

- Research, develop, and widely distribute phased evacuation plans that create reasonable time bands (e.g., approximately 30 minutes for a highly urban fire)
- Use known boundaries and easy to identify landmarks and roads to set evacuation zones for phasing
- Maintain a relatively small number of potential zones to reduce confusion in the evacuation process and reduce the number of messages sent to evacuees
- Convey emergency evacuation orders and warnings by zones
- Prepare for contingencies (i.e., changes in time bands) if the fire spread is faster or slower than expected

Feasibility

Dividing the fire-prone area into zones is an effective way to move as few people as needed to safe areas (83). In practice, agencies can construct evacuation zones based on both natural (e.g., vegetation type) and human factors (e.g., landmarks, clearly defined roads) (84,85). The initial research can be done as a desktop study, as the vegetation coverage map, the road network map, and other geospatial information can be readily obtained from sources such as the LANDFIRE program and OpenStreetMap. During the development stage, refinement can be made through meetings with the emergency responders and the wider community (14). Prior to wildfires, residents need to be informed of their zones, potentially through letters sent to homeowners and renters or announcements via online neighborhood hubs such as Nextdoor. Interactive zone maps for the jurisdiction can also be created easily using tools such as ArcGIS online (e.g., Berkeley Evacuation Zone Map from (86)). During the wildfire, geo-coded alerts can be sent to residents in targeted zones. For example, alerts can be sent to the residents in specific areas through FEMA's Integrated Public Alert & Warning System (IPAWS) system through multiple pathways using commercial software (87,88). However, reliability of the software could be problematic, as previous technical difficulties have been reported (89). Lastly, zone-based phased evacuation may not work as planned if the fire spreads too quickly. In such case, public agencies may need to use a variety of communication tools (e.g., radios, phone calls, social media platforms, person-to-person interactions) to keep evacuees informed (62).

7. Instituting Contraflow	Moderately Recommended

Description

Contraflow strategies can reduce the exposed vehicles from the fire frontier. Extending the contraflow operation beyond the immediate boundary of the evacuation zone can help to further improve the ETEs. However, contraflow tends to be an expensive procedure that requires significant pre-planning, time to executive, and personnel. For resource-strapped or smaller agencies, contraflow may not be a viable option.

Recommendations for Emergency Management and Transportation Agencies

- Develop contraflow plans that focus on highly congested roads, arterials, and neighborhoods with few exits to maximize effectiveness and minimize resource needs
- Notify evacuees ahead of time of the plan to switch lanes to flow in the opposite direction
- Consider potential turning or merging conflicts when designing contraflow routes
- Pre-plan traffic operations (e.g., changing signals to prioritize traffic away from the fire) and consider congestion-reducing mechanisms near the end of the contraflow to minimize bottlenecks and upstream queuing in the fire frontier

Feasibility

The practicality and benefits of contraflow has been demonstrated mainly in hurricane evacuations. However, its success is heavily dependent on proper planning and execution. Early studies pointed out several factors that might prevent contraflow from achieving its optimum outcome. On the planning level, limitations include the cost of planning and infrastructure changes, safety implications, confusion caused by evacuees' unfamiliarity to the arrangement, and reduced access for service and emergency vehicles (90). On the operational level, especially on urban roads/arterials, challenges remain in identifying contraflow links analytically, disseminating contraflow information timely, and maintaining traffic flow through reversed lanes and intersections (91). However, it has been shown that simple and inexpensive actions, such as providing enough entrance capacity and carrying out merges after the evacuation area, can greatly improve contraflow efficiency (92,93).

6. CONCLUSIONS

In this study, we developed a spatial-queue-based dynamic traffic simulation model that incorporated behavioral data from post-disaster wildfires in California. This simulation model was applied to a wildfire evacuation case in the Berkeley Hills Area of Berkeley, California. To incorporate realism, we considered a range of variables including fire speed, departure time, destination choice, mode choice, number of towed vehicles, queuing, rerouting, and two policy strategies (e.g., contraflow, phased evacuation). We aimed to produce a data-driven model that could identify possible transportation response strategies for agencies with minimal time, funds, resources, or knowledge to respond to a wildfire evacuation. Compared to other evacuation models, the incorporation of behavioral data, focus on policies and strategies, and realistic details (e.g., dynamic routing, parcel level data, complicated street network) signify an important step for the field.

We found strong indications that phased evacuations, vehicle rerouting, and reduction in personal vehicles were the most effective strategies for reducing the number of exposed vehicles in the fire frontier and/or the evacuation time estimate (ETE). Implementing these strategies, while challenging, would not be unrealistic for small and/or poorly resourced emergency management and transportation agencies. The strategies would require substantial pre-disaster communication and accurate, timely messaging during the wildfire. Contraflow for an extended length beyond the evacuation boundary was also found to be effective in reducing ETEs and exposed vehicles. However, this strategy would be potentially hard to implement for resource-strapped agencies if guidance is required at every intersection. A vehicle rerouting strategy may also require new partnerships with GPS-based mapping platforms (e.g., Google Maps, Apple Maps, Waze). In addition, the phased evacuation results showed that too small or too large of time intervals would be less efficient, suggesting a need for thoughtful planning. We also found moderate improvements in evacuation outcomes for implementing contraflow (for short lengths under resource constraints) and slowing fire speed *for our case study*. In combination with other strategies, these responses may prove to be highly useful under different conditions (e.g., for a different road network).

Given the level of details that the simulation can support (e.g., road network, vehicle behavior), there are many assumptions involved that have been documented extensively in Section 3 and offer broader application. Specifically, the intended application of this simulation is for preparedness analysis and reconnaissance of real events, where reasonable assumptions can be made based on local knowledge or post-event surveys. For example, for many resource-strapped communities in the WUI area, it is imperative to understand the most cost-effective precautionary measures and implement corresponding policies. This best-working strategy is likely to be different for each community, thus a flexible simulation model framework such as the one presented in this paper becomes valuable. The model can be adapted to incorporate local knowledge-based assumptions to find the critical policy scenario specific to the local context. For post-event reconnaissance, (64) presented the application of a similar framework in Paradise, CA to simulate the Camp Fire evacuation. In that study, the assumptions were made according to the field interviews with local officials. Consequently, the modeling approach in this paper demonstrates the applicability of the simulation framework to analyze alternative scenarios and gain valuable lessons from reconstructing past events.

However, more research is needed on this topic based on the limitations of the paper. For example, the model could use additional realism through better post-disaster data (including verification with mobile phone data) and integration with a fire spread model. The model also requires application across more jurisdictions in California, in North America, and globally for generalizability assessments. Most critically, work is needed to link this model to a transit-based evacuation model that better incorporates the needs of vulnerable populations and includes data on how vulnerable populations make decisions in wildfire evacuations. With increasing frequency and size of wildfire evacuations, realistic and practice-oriented models that incorporate behavioral realism will become even more critical to ensure that *all people* are safe.

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8. AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: B. Zhao, S. Wong; data collection: S. Wong; modeling: B. Zhao; analysis and interpretation of results; draft manuscript preparation, results review, and final approval: all authors.

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