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The Speed of Fire: An Evaluation of Emergency Planning and Alerts in Extremely Fast Moving Wildfires

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<https://escholarship.org/uc/item/5dp5c32j>

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Publication Date

2024-02-06

The Speed of Fire:

An Evaluation of Emergency Planning and Alerts in Extremely Fast Moving Wildfires

The Camp Fire decimated Paradise, CA moving as fast as 80 football fields a minute. Evacuation plans for the city required three hours, but the fire reached the town in less than 90 minutes. This was faster than firefighters could hope to respond and hours before the first emergency alert was sent. Residents were left to evacuate alone when they saw flames out their windows. By the time the fire ended 85 people lost their lives and 95% of the town was flattened. It is easy to say this was an unprecedented event but through a review of six extremely fast-moving wildfires in California between 2017-2018 the Camp, Carr, Atlas, Tubbs, Nuns, and Woolsey fires I will demonstrate how repeated failures in emergency planning and alert systems have left communities unprepared for extremely fast-moving wildfires and identify areas for improvement. Using a review of emergency plans I identify a lack of plans to identify, transport, or provide any service for vulnerable populations which I connect to the resulting fatalities using a histogram showing the ages of the fatalities. I then use After Action Reports, Reviews, and Grand Jury Reports to review the activation and success of emergency alerts. Using this I then prepare a set of recommended conditions that should be assumed when preparing an emergency plan including the complete loss of power and telecommunication towers and the need for shelter-in-place preparations.

Significance:

Nearly 11.2 million people lived in high-risk wildland-urban interface areas in 2020 a number that will continue to increase as housing prices are pushing people to build and live in riskier areas(Green, 2021). Combined with an aging population that is estimated to reach 8.4 million

over 65 by 2030 this creates a 'perfect storm' of vulnerability while at the same time we are seeing more extreme fire events(UNEP, 2022 and Stanford Center on Longevity, 2012). Half of California's largest fires occurred within the last five years and between 2020 and 2021 seven of those occurred showing a concerning escalation in fire activity(CalMatters, 2023). This is especially worrisome because a 100,000-acre fire releases the same amount of carbon as seven million cars running straight for a year(Neal Driscoll, 2023). Between 2017 and 2018, 3,523,515 million acres burned the equivalent of 247 million cars running for a year(CalMatters, 2023). The staggering impact on the environment and public health is not being accurately included in air quality indexes limiting our ability to accurately understand the impact of wildfire emissions(Peterson & Bergin, 2023). Outdated regulatory requirements for data collection, analysis, and publication to the public are leaving us with a concerningly sparse picture of the impact of wildfires in California and are severely limiting our ability to respond effectively. At the same time, the cost of CalFires fire suppression efforts has skyrocketed. For the first time in Californian history in 2020 CalFire suppression costs surpassed one billion(CalMatters, 2023). It is not surprising traditional firefighting methods are ineffective because fires are becoming so extreme they create their own weather. Pyrocumulonimbus clouds are made when fires cause warm air to rise creating storm clouds that can produce dry lightning potentially starting more fires. Fire tornadoes which are extremely dangerous have already been filmed in the Camp and Carr fires(Spencer, 2021). These formerly unprecedented conditions demonstrate the need for improved and innovative approaches to emergency alerts and evacuations. Wildfires create a positive feedback loop where increasing temperatures, compression of the wet season, and atmospheric vapor pressure deficit caused by climate change leads to dryer fuels and more extreme weather which causes more extreme wildfires increasing emissions which drives

climate change. The suppression of indigenous fire and land management practices, historic fire suppression, logging practices, and lack of fuel management have caused a build-up of dry vegetation exacerbating this relationship (MacDonald et al., 2023). Even if we started planning today with the improved technology and an unlimited budget it is likely wildfires where no emergency alert is sent and no evacuation transportation is provided would still occur before we could implement solutions.

Background:

Current regulations do not require counties to have emergency plans or set requirements for preparation. This creates a significant amount of variability between counties that are provided FEMA and state guidelines they may choose to follow to any degree. Fires like these rely on mutual aid from a variety of fire and law enforcement partners who struggle to respond effectively in fast-moving emergencies using unfamiliar systems (Venton, 2023). We are not prepared to respond after fires occur. In Paradise, CA following the Camp Fire, two billion was spent removing burned structures dangerous to human health but no improvements to zoning regulations created 'fire antagonistic' neighborhoods where a lack of buffer space and other considerations make fuel reduction extremely difficult where made (Venton, 2023). The state government's lack of interest in regulating after wildfires occur and the desire to rebuild without changes is severely damaging our ability to make meaningful change.

Research from Tom Cova is leading the field of wildfire preparation and fatality reduction where there is a lack of connection between modeling and implementable recommendations. Cova has created a dire warning scenario model that simulates routine, dire, very dire, and extremely dire evacuations. The model uses a comparison between fire speed and evacuation time to rate fires based on severity and risk to life which is more effective at evaluating fires that exceed previous

worst-case scenarios. In a routine fire, the evacuation time is less than or equal to the lead time of the wildfire and in an extremely dire fire, the evacuation time is at least twice the lead time of the fire. Using these models Cova recommends investment in fire shelter safety zones a practice not popularized within the US but that became necessary when residents sheltered in place in parking lots during the Camp Fire (Cova et al., 2021). Cova's research is the first to model situations comparable to the speed and evacuation time seen in the 2017 and 2018 fires and demonstrates large gaps in research for unpredictable and catastrophic wildfire events.

Tim Haney's research as the director of the Center for Community Disaster Research in Alberta led to his creation of a planning 'checklist'. He looks for: distinctions between slow and fast-moving disasters, plans for vulnerable low-income, elderly, disabled, without a car etc including where they are concentrated relative to hazards and what transportation they will need, a plan for what people should do when they hear an evacuation order but choose not to leave, an estimated number of people needed shelter, where the shelters will be set up, accommodation for pets in shelters and plans for continuity of emergency social services like mental health providers(Haney, 2021). There is a concerning lack of research in this field especially that specifically addresses wildfires and almost no research on the effectiveness of our current emergency alert systems outside of the language used in messages.

Current Legislation:

Legislation for wildfire response is a complex combination of State and local government laws. Disability Rights California identifies the current regulations around disability and elderly evacuation that require updates, warnings, and alerts to be accessible, access to transportation if there is an evacuation order, and accessible emergency shelter(Disability Rights California, 2021). During fast-moving wildfires, evacuation warnings are not communicated and no

evacuation transportation is activated these rights are not fulfilled. This highlights why we need updated evacuation codes for disabled residents that include specific requirements for planning for rapid evacuations.

In 2018 California Governor Brown signed a variety of bills to address issues around prevention and recovery. Three of these specifically address emergency communication. SB 833 by Senator Mike McGuire requires the Office of Emergency Services alongside stakeholders to develop voluntary guidelines for emergency notifications. SB 821 by Senator Hannah-Beth Jackson authorized counties to make agreements with public utility companies to access the contact information of customers and enroll them in emergency warning systems. Importantly AB 1877 by Assemblymember Monique Limón requires the Office of Emergency Services to create a library of translated emergency notifications(California, 2018). These are important steps in addressing communication needs but legislation needs to address the continued failure of our state-level alert systems(Nexile, CodeRed, SoCal Alerts, and other reverse 911 systems) as well as federal-level alert systems(Wireless Emergency Alerts(WEA) and Emergency Alert System(EAS)). Failures in activation protocols, system knowledge, and telecommunication infrastructure are rendering already-dated systems even less effective.

Maintenance and fuel reduction along evacuation routes are addressed in the “California Wildfire and Forest Resilience Action Plan” published by the Governor's Forest Management Task Force in 2021 and in the CAL FIRE Wildfire Prevention Grants Program which received an additional \$113 million in new funding through the California Climate Commitment budget(California Wildfire and Forest Resilience Task Force, 2022). These plans and grants develop funding to reduce overall vegetation and create fire-safe roads increasing the defensible space on both private property and public lands(California, 2023b). Government Code 65302

requires local governments to identify residential developments with fewer than two evacuation routes. This is important for rapid evacuations when bottlenecks are a significant concern. Government Code 65302.15 requires local governments to “identify evacuation routes and their capacity, safety, and viability under various emergency scenarios”(Technical Assistance for Local Planning, 2021). Problems arise because counties are not required to have publicly available emergency evacuation plans or route maps. Even when using freedom of information requests counties have little pressure to provide complete plans. A USA Today investigation in 2019 found only 22% of high-fire-risk counties in California had thorough and accessible emergency plans. New legislation requiring publicly published emergency plans and evacuation routes is a vital first step in planning. Without this information, planners cannot effectively evaluate areas for improvement or potentially penalize counties out of regulation. A review of current legislation shows critical progress made on fuel reduction projects which will reduce extreme fire risk but a concerning lack of action on alert infrastructure, emergency transportation, and funding for local-level planning necessary to address the loss of life in the 2017-2018 wildfire season(U.S. National Park Service, n.d.).

Theory and Argument:

I propose an evaluation of census data, emergency plans, and After Action Reports that will highlight vulnerabilities in emergency planning and response requirements for extremely fast-moving wildfires in California between 2017 and 2018. The American Community Survey collects data on the number of residents over 65, with a disability, living in poverty, and without a car, which are factors identified in Tim Haney’s research that increase vulnerability in evacuations. I can then review emergency plans for specific identification of these populations, plans to address specific communication needs, and most importantly specific transportation

plans for evacuations where they are more likely to not be able to self-evacuate. Then using After Action Reports, Reviews, and Grand Jury Reports in combination with news articles I will evaluate the activation of emergency alerts. I expect to see a higher number of fatalities in areas with more demographic vulnerabilities, a lack of specific evacuation plans for these residents, and failures of the emergency alert systems. I expect this causal relationship to exist because the more people without transportation and who are not alerted of the fire the slower they will be able to respond to extremely fast-moving fires.

Other possible explanations include the concentration of dry fuels around transportation routes which can increase the severity of fire behavior in these areas. More congestion between the number of people evacuating and the number of evacuation lanes can lead to bottlenecks and congestion increasing the time available to evacuate. Emergency planners also fear that sending evacuation orders could lead to more congestion on the roads because current technology is not very specific and can send alerts to people who are not in danger and do not need to evacuate.

Planning and preparation can also be delayed due to a lack of public pressure and a lack of knowledge about the level of preparation. Instigating an investigative report into a county's emergency plan is almost guaranteed to identify concerning gaps in planning and can bring negative attention to the county.

Emergency planning must try and prepare for increasingly complex, unpredictable, and extreme events. How can a review of American Community Survey census data, emergency planning documents available on county websites, and After Action Reports, Reviews, and Grand Jury reports supplemented with news articles identify gaps in emergency planning and highlight areas for improvement specifically with already existing technologies?

Research Design and Data:

Using comparative case studies I reviewed six extremely fast-moving wildfires that occurred in California between 2017 and 2018. The fires were selected using a combination of the number of resulting fatalities and the speed at which the fire approached communities. All fires met at least two conditions. They caused more than two fatalities and had the at which the fire approached communities identified as a significant factor in the reports published by the county after the fire occurred.

To measure the ages and number of both civilian and firefighter fatalities I used a combination of coroner reports, news reports, and most significantly CalFire summary data. There are several missing data points for the ages of fatalities most significantly for the Camp fire presumably due to the large number of lives lost. Deaths due to smoke, stress, or other reasons not directly caused by the fire were not counted due to a lack of data. Additionally, data on the disabilities, poverty, and status of car ownership among fatalities is not available but should be investigated in further research. The number of fatalities was chosen to measure the number of people who both failed to reserve evacuation support and who could not self-evacuate. Other residents met this level of need but were evacuated by members of the community or sheltered in areas not previously identified in planning documents available to the community.

American Community Survey census data was used to identify the number of residents over 65, with disabilities, living in poverty, and without a car present in the census-designated place in the year before the fire occurred. These variables were chosen to represent vulnerable demographics as identified in FEMA evacuation planning documents(*Planning Guides*, 2023). The census data is regarded as the best population data available in the US and has a high regress of validity.

When available 1-year American Community Survey data was used but 5-year estimates were also supplemented for areas too small to have 1-year data(US Census Bureau, 2023). Data for the

Altas, Nuns, and Tubbs fires was combined by adding the total population of all three census-designated areas and the number of residents with vulnerabilities and finding the overall percentage because there was significant overlap between these fires. They occurred at the same time, impacted the other's evacuation routes, and would have created misleading data if evaluated separately.

Those over 65 and those with mental and physical disabilities as defined by the American Community Survey are more vulnerable during wildfire evacuations(California Wildfire and Forest Resilience Task Force, 2022). This can increase the difficulty of making rapid decisions during a wildfire when smoke and fire can obscure road lines, roadway signs, and a lack of accessible information can easily lead to panic, further complicating decision-making.

Additionally, these populations can be more vulnerable to smoke inhalation which can cause dizziness, confusion, shortness of breath, decreased alertness, chest pain, acute respiratory distress, and respiratory failure further complicating self-evacuation(Santos-Longhurst, 2018).

Medical equipment like oxygen tanks and assistive technology like wheelchairs can also complicate people's ability to self-evacuate or use available transportation, additionally increasing their vulnerability.

This data was then compared to California averages from the year 2017 before all the fires included in this review to show the relative concentration of these populations in relation to California(US Census Bureau, 2023). The relative concentration of retired elderly residents in these areas may be increased because wildland-urban interface(WUI) areas were advertised as retirement communities and are cheaper in some cases(Green, 2021). This measure is imperfect because residents over 65 or with a disability may be able to self-evacuate but it is the best data

available to represent increased risk. Further data collection for planning should identify the number of residents who cannot self-evacuate separate from age and disability rates.

Planning for residents with disabilities and who cannot self-evacuate was collected using emergency planning documents available on county and city websites. I then separated plans that only mentioned the increased vulnerability of people with disabilities during evacuations from those who had more specific plans to transport or shelter people. To qualify as a specific plan it had to include details on how to sign up for emergency assistance and transportation, provide details on how and where that would be provided, and have working links to provide additional information. Programs for those with disabilities that only provide planning documents and additional information were not included. This measure is imperfect because most areas had more information available upon request that I was not able to access by contacting the county. It also cannot measure if these programs are regularly updated, including regular training, or if they will be functional during an emergency.

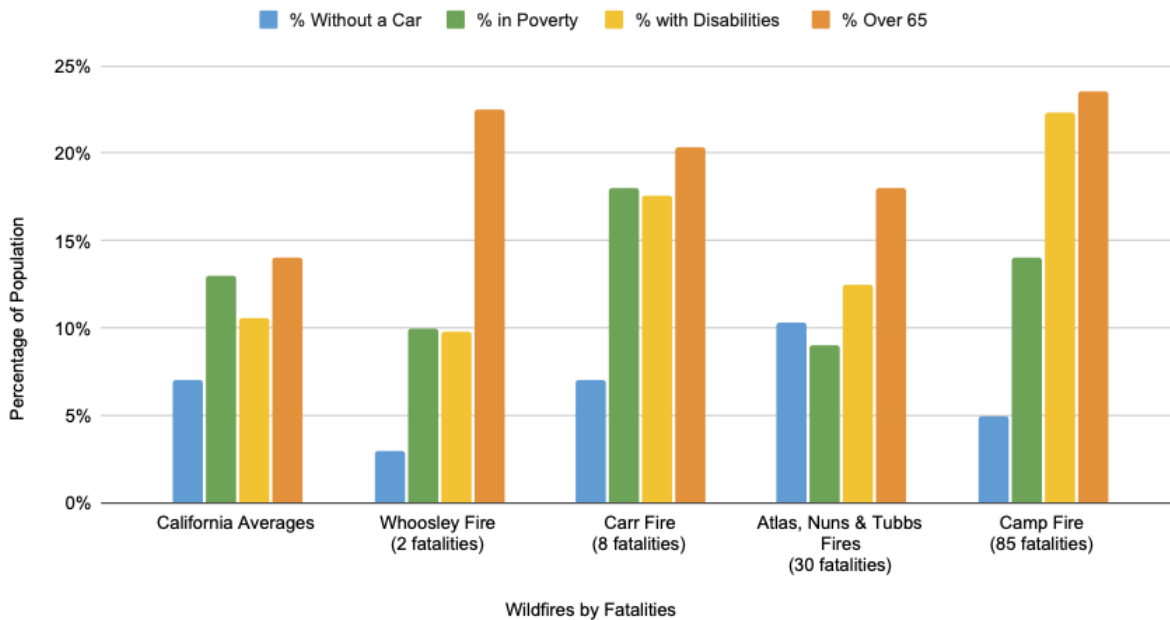
The success of emergency alert systems was measured using a combination of county-released reports and news articles with both county data and first-hand reports to supplement missing information. Information on the use of emergency alerts was mainly identified in the fire timelines published in these reports but was identified as a major point of failure in all fire reports reviewed. Through a review of After Action Reports, After Action Reviews, and Grand Jury Reports as available I identified all systems activated during wildfires and if it was successfully activated. Ideally, this measure would include more detailed data to increase the reliability of the information but there were significant limitations.

Reports published by counties were further complicated when fires impacted multiple jurisdictions because these reports mainly focused on the success of the chain of command and

mutual aid within fire and police departments. Data on the time between firefighters or police deciding the alert should be activated and calling it into a dispatch center and the time the signal was sent to telecommunications towers is not available. Some incomplete data on the success of the alerts after they are sent to telecommunications towers and then to residents' phones is available but was too scattered and unreliable to include. The actions of county-level planners when attempting and failing to activate the alerts were also unreliable. In many cases, county records and alert system records of activation attempts often conflicted. Even the percentage of residents who signed up for voluntary alert systems before these fires occurred was not available. The significant amount of missing or incomplete data limited my evaluation of emergency alerts' success and should be the focus of both legislation, regulation, and further research.

To identify specific systems of alert I first identified which alerts used telecommunication towers that house technology for television, radio, wifi, wireless, and cellular systems. I then separated systems that used text, call, email, and reverse 911 systems but could not bypass signal congestion from the wireless emergency alert which uses the same paths but can bypass signal congestion. I then separated the emergency alert system because it is unlike the others because it is not a voluntary sign-up service and uses TV and radio signals. Other categories include door-to-door evacuation using bull horns, air horns, and police car-mounted siren systems including specific hi-low sirens used for evacuations. The last type of alert is the outdoor emergency siren which is importantly not attached to a police car, not reliant on power or telecommunication tower signals, and is physically built in the town. One other method identified was helicopter PA systems but this was not included for simplicity and because I could not identify a case where it was activated during a wildfire.

Demographic Vulnerabilities Before Wildfires Occurred

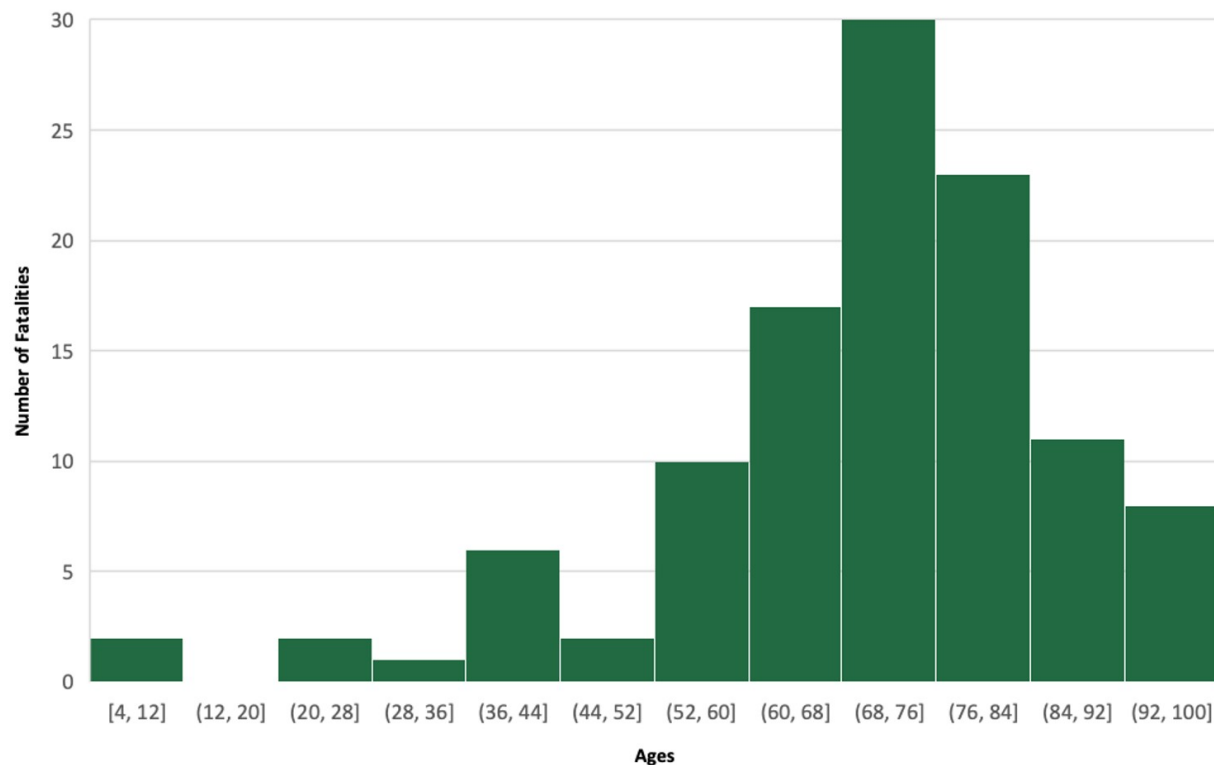


Analysis:

Overall analysis showed higher levels of those over 65 and with disabilities in areas with wildfires, higher fatalities in older individuals, and significant failures in planning and alert systems. Comparing the demographics of age, disability, poverty, and lack of a car to the California average did not show significant overall trends. There was lots of variation in the number of residents without a car and in fact in the deadliest fire the Camp fire there was a lower percentage of residents without a car than the California average. This is likely due to the wildland-urban interface's relatively remote locations largely not accessible by public reliable transportation. The number of residents living in poverty did not show a significant difference between the wildfires and California averages. These factors could be more significant when used to evaluate the distribution of fatalities or when data on residents' ability to drive their car is specified and not just access.

The percentage of residents with disabilities is higher than the California average in all fires besides the Whoosley fire which resulted in the lowest number of fatalities at only two. The percentage of residents in Paradise where the Camp fire with the most fatalities occurred was nearly double the California average and the Carr fire with eight fatalities was more than seven percentage points higher. There is too little data to imply a relationship between the number of residents with a disability but this suggests that it increases the vulnerability to fatalities.

Ages of Wildfire Fatalities



The percentage of residents over 65 was much higher, more than five percent higher than the California average in all the fires reviewed which when compared to a histogram of the ages of fatalities demonstrates this may be the most significant demographic vulnerability. There is a clear spike of fatalities between the ages of 65 and 85 with almost very few deaths between the ages of 0 to 50. This shows that elderly residents are more likely to die in a wildfire. The range of

ages was between 4 years old to 100 years old leaving mostly the very young and very old vulnerable.

Emergency Alert Systems Activated

	Text, Call & Email	Wireless Emergency Alert	Emergency Alert System	Door to Door	Physical Sirens
Nuns Fire (2 fatalities)	>50% delivered	Failed to Activate	Failed to Activate		Non Available
Woosley Fire (3 fatalities)	No Alert System	Failed to Activate	Failed to Activate		Non Available
Atlas Fire (6 fatalities)	>50% delivered	Awaiting Federal Approval	Failed to Activate		Non Available
Carr Fire (8 fatalities)	>50% delivered				Non Available
Tubbs Fire (22 fatalities)	>50% delivered	Failed to Activate	Failed to Activate		Non Available
Camp Fire (85 fatalities)	>50% delivered	Failed to Activate	Failed to Activate		Non Available

To review the use of alert systems I included both if the system was activated and an indication if the alert reached more or less than 50% of residents because specific data was not available. Door-to-door alerts were used in all fires as a last resort. Text, call, and email systems were the second most activated with $\frac{5}{6}$ fires using this system. Significantly the Whoosley fire area had no alert systems at all besides door-to-door police making it especially surprising it had the lowest number of fatalities. In all cases when the text, call, and email systems were activated they reached less than 50% of residents, likely a significantly smaller number. It is unlikely more

than 10% of residents were reached by any notification through any alert system because in all cases the alert was sent after telecommunication towers on which they rely were damaged or destroyed. The federal systems of wireless emergency alerts(WEA) and emergency alert system(EAS) were only activated during the Carr fire. In at least one other fire, the Atlas fire the county was still waiting for federal approval to use the system but in all others, it was not activated. The final system of outdoor sirens was not used in any fire reviewed and is not standard in the area.

Implications:

California does not know how prepared it is for wildfires let alone come close to being prepared to evacuate or alert our residents. We have no concrete understanding of the number of vulnerable residents who cannot self-evacuate, no recommendations in most areas for the routes to take during an evacuation let alone a specific and accessible plan for evacuations. Our plans do not even attempt to identify possible locations to implement shelter-in-place protocols despite them being used in almost every fast-moving wildfire. It is extremely unlikely more counties in high-risk fire areas comply with current regulations and even those who have comprehensive and accessible plans do not include any plan to transport residents.

Paradise where the Camp fire occurred and Sonoma County where multiple fires have occurred do not have the most comprehensive plans available and should continue to be used as a model for other areas. Many of the areas where the fires occurred have also now used FEMA disaster mitigation and preparation funding to put in physical sirens. The state government should allocate additional funding to supplement this program. My strongest recommendation is the implementation of outdoor sirens because in all the fires that occurred telecommunication

towers were damaged or destroyed and power was out. This is the only system that will continue to function in these conditions and have applicability for alerts in many other emergency events.

Additional research is needed to implement transportation and shelter-in-place protocols for residents who cannot self-evacuate. We lack the necessary information on the best way to shelter in place in highly forested areas. Shelter-in-place protocols are common in Australia and this topic highlights opportunities for international collaboration as we research how to tweak those protocols for our environment.

The biggest finding and implication from my research is the need for research, funding, and support in local-level emergency planning. Without concrete recommendations and requirements, local governments are left in the dark as they try to prepare for increasingly severe wildfires. There needs to be more dire assumptions when developing plans. For example, planners should assume the complete loss of power and telecommunication towers is highly likely. There needs to be significant efforts to take our emergency preparation out of the ‘dark ages’ and update it to the level necessary for the climate-impacted events we are continuing to see. At a smaller level improvements look like moveable and changeable traffic signs and changeable traffic lights that can be used to facilitate evacuation but our current plans are so out of date it would be exhaustive to list the number of improvements that need to be made.

Specifically within the alert systems used, there is a need for statewide consistency. Emergency responders often do not know who is in charge of activating alerts, the protocols to activate them, or even what alerts their county uses. In the Sonoma County fires, there were 911 dispatcher conversations recorded where a firefighter called to activate the system, and the dispatcher said they didn’t even know what system they were referring to (Hutson, 2018). These

problems could be more efficiently reduced if there was a single system of alerts for California and regular training were conducted.

Conclusions:

Our current level of preparation was sufficient when wildfires took days or even multiple hours to reach populations but as we saw in the Camp Fire where planners assumed they would have three hours and the front reached the community in less than 90 minutes those assumptions are no longer accurate. Scientists have demonstrated that climate change is happening more rapidly than expected (Tollefson, 2022). Most of the conversations around our response are based on reducing our carbon emissions and mitigating extreme weather events. Both are vitally important but we also need to take a serious look at how prepared we are to respond to those disasters, especially for the elderly and disabled. If we continue our current practices there will be significantly more wildfire fatalities. Areas like Lake Tahoe with a number of tourists unfamiliar with the area, non-English speakers, high fuel load, no emergency sirens, and extremely congested roads are at extremely high risk of a high fatality event if a fast-moving wildfire happens. The area has been threatened before by wildfires yet there is little interest from the public or local officials to make the necessary changes to prepare for such an event. Imagine a wildfire similar to the Camp Fire with high wind speeds, moving as fast as 80 football fields a minute and approaching the South Lake Tahoe area in under two hours during peak tourism season with no warning. Where would people go? How would local governments warn people, especially non-locals? How would the local governments be able to respond? These are the critical questions that should be asked at the state legislature, in the US, and across the world. Wildfires are only going to get worse.

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