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Accessibility, Infrastructure, and Systemic Failures in the 2025 Altadena (Eaton) Wildfire: A Wildland–Urban Interface Analysis of Emergency Evacuation Systems

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Abstract

The 2025 Altadena (Eaton) wildfire in Los Angeles County represents a critical case study in wildland–urban interface (WUI) disaster vulnerability, highlighting systemic deficiencies in evacuation infrastructure, accessibility planning, and governance. The event demonstrates how physical hazards, when combined with constrained road networks, limited accessibility integration, and emergency-response challenges, can disproportionately affect vulnerable populations.

This study employs a mixed-methods case-study approach incorporating GIS-supported spatial analysis, conceptual–semi-empirical evacuation modeling, accessibility analysis, regulatory comparison, and review of government, agency, media, and documentary survivor accounts.

Findings indicate that the Eaton Fire exposed weaknesses in:

1) Evacuation-route redundancy, 2) Emergency communication, 3) Accessibility integration, and 4) Coordination among interdependent systems.

Applicable California and Los Angeles County requirements are distinguished from model codes and later standards used only as comparative resilience benchmarks. The findings identify a community-scale coordination gap among independently administered life-safety systems and support the proposed Accessible Wildfire Evacuation Model (AWEM), an integrated framework linking wildfire exposure, evacuation infrastructure, emergency communication, accessibility, and emergency-response coordination to improve equitable WUI evacuation resilience.

Keywords: Altadena Wildfire; Wildland–Urban Interface (WUI); Wildfire Evacuation; Wildfire Risk Management; Road Network Constraints.



1. Introduction

The Altadena wildfire burned approximately 14,000 acres, destroyed over 9,400 structures, caused at least 19 fatalities, and triggered large-scale evacuations, making it one of the most destructive wildfire events in California's recent history (CAL FIRE, 2025)¹. Wildfires in the wildland–urban interface (WUI) continue to increase in frequency and severity due to climate change, urban expansion, and land-use practices (Radeloff et al., 2018)²; (Syphard et al., 2017)³. The 2025 Altadena wildfire, occurring in the foothill communities adjacent to Eaton Canyon, provides a compelling case study of how topography, infrastructure constraints, accessibility, and emergency preparedness intersect to influence evacuation outcomes.

Wildfire evacuation in established WUI communities depends not only on fire behavior but also on the interaction of roadway configuration, warning and communication systems, transportation availability, accessibility needs, and emergency-response coordination. These interdependencies are particularly important for older adults, people with disabilities, medically vulnerable residents, and others who may require additional warning, transportation, or evacuation assistance. Accordingly, the Altadena case provides an opportunity to examine wildfire evacuation as an integrated community-scale life-safety problem rather than solely as a fire-suppression or building-level issue.

- Altadena presents a canyon–foothill configuration in which residential development is situated within a transportation network influenced by topography and limited route redundancy.

During rapidly evolving, wind-driven wildfire conditions, these characteristics may constrain evacuation movement and increase dependence on a limited number of outbound routes.

This study therefore evaluates: (1) the relationship between road-network configuration and evacuation performance; (2) the influence of accessibility limitations on older adults, people with disabilities, and other vulnerable populations; (3) the effectiveness of emergency communication, governance, and response coordination; and (4) the extent to which applicable California and Los Angeles County regulatory requirements, together with relevant comparative WUI and accessibility standards, address community-scale wildfire evacuation conditions.

2. Objectives

The primary objective of this study is to evaluate, through spatial, qualitative, regulatory, and conceptual–semi-empirical analysis, how infrastructure design, accessibility integration, emergency communication, and governance systems influenced evacuation conditions during the 2025 Altadena (Eaton) wildfire. Within the WUI context, the study examines interactions among roadway configuration, wildfire progression, accessibility constraints, emergency communication, and human response under extreme conditions.

- Focusing on the wildland–urban interface (WUI) context, the research examines how road network limitations, fire dynamics, and human behavior interact under extreme conditions.

2.1 A key component of this objective is the assessment of evacuation infrastructure performance, including network capacity, connectivity, and redundancy, and how these factors contributed to congestion, delayed evacuation, and reduced survivability.

2.2 The study also aims to analyze accessibility as a life-safety system, evaluating whether evacuation routes and support mechanisms were usable by all populations, particularly vulnerable groups such as the elderly and people with disabilities. This includes assessing the availability of accessible transportation, continuity of ADA-compliant routes, and the presence of coordinated assistance systems.

2.3 In parallel, the research evaluates the effectiveness of emergency communication systems, focusing on the timing and clarity of evacuation alerts, and how delays in warning dissemination affected evacuation initiation and overall system performance.

2.4 Finally, the study evaluates regulatory and governance integration by examining inter-agency coordination, decision-making processes, applicable California and Los Angeles County building, fire, accessibility, WUI, and planning requirements, and relevant comparative standards. The analysis distinguishes requirements applicable at the time of the Eaton Fire from later or independently non-applicable provisions used only as prospective resilience benchmarks.

3. Methodology

This study applies a mixed-methods case-study framework to evaluate evacuation-system performance during the 2025 Altadena (Eaton) wildfire. The analysis integrates GIS-supported spatial assessment, documentary and survivor-account review, conceptual–semi-empirical evacuation modeling, accessibility analysis, and comparative regulatory review. The purpose is to examine how roadway configuration, wildfire exposure, emergency communication, accessibility constraints, land-use conditions, and institutional coordination interacted during the event.

3.1 Data Sources and Evidence Collection

Data were drawn from publicly available government and agency reports, GIS and mapping resources, media investigations, published survivor and eyewitness accounts, field observations, regulatory documents, planning materials, and relevant wildfire-evacuation literature. Sources included CAL FIRE, Los Angeles County, FEMA, local planning information, wildfire-perimeter and land-use mapping, accessibility-related media accounts, and published research concerning WUI development, evacuation behavior, emergency communication, and vulnerable populations. Documentary survivors and media accounts were treated as secondary qualitative evidence and were analyzed separately from any direct research participation.

3.2 GIS and Spatial Analysis

GIS-supported analysis examined roadway connectivity, canyon and foothill topography, evacuation-route redundancy, potential bottlenecks, residential development patterns, proximity to wildland vegetation, and the relationship between the Eaton Fire perimeter and developed areas.

Spatial evidence was compared to identify locations where topography, limited roadway connectivity, or dependence on a small number of routes could constrain evacuation movement. The analysis was qualitative and comparative rather than a calibrated traffic-simulation model. GIS evidence was used to support interpretation of route vulnerability, WUI exposure, congestion potential, and evacuation redundancy within the Altadena case study.

3.3 Evacuation and Network Analysis

Roadway and evacuation-system performance were evaluated using observed network configuration, documented congestion and evacuation conditions, survivor/media accounts, emergency-response information, and established evacuation literature.

The analysis considered route continuity, route redundancy, bottleneck potential, interaction between evacuation traffic and emergency-response access, and the relationship between warning timing and available evacuation time. No direct roadway-capacity measurements, traffic counts, or calibrated origin–destination models were available for this study; therefore, network findings are interpreted as case-study evidence of relative evacuation constraints rather than measured transportation-performance values.

3.4 Conceptual–Semi-Empirical Modeling

Charts 1–6 present conceptual–semi-empirical models developed from the combined evidence streams. The models use normalized relative indices to illustrate relationships among wildfire exposure, evacuation capacity, warning timing, accessibility, infrastructure performance, regulatory integration, and community resilience.

Values shown on 0–100 scales are dimensionless analytical indices used for comparative visualization and do not represent measured population percentages, actual roadway capacities, probabilities, validated failure rates, code-compliance percentages, or calibrated predictive outputs. Curve direction and relative behavior were informed by GIS observations, documented wildfire and evacuation conditions, agency reports, survivor and media accounts, and relevant wildfire-evacuation literature. The specific numerical values assigned to individual curve points are illustrative normalized values rather than independently measured or statistically estimated quantities. Accordingly, the models are explanatory rather than predictive.

3.5 Accessibility and Vulnerable-Population Analysis

Accessibility analysis examined barriers affecting older adults, people with disabilities, medically vulnerable residents, and households requiring evacuation assistance. Evidence was reviewed for recurring themes involving mobility limitations, accessible transportation, warning access, caregiver dependence, medical support requirements, language and communication barriers, and coordinated evacuation assistance. Publicly reported survivors and media accounts were coded thematically according to the principal accessibility barrier and reported evacuation consequences.

These accounts were treated as documentary evidence rather than population-level statistical findings. Recurring observations across multiple independent sources were considered supportive of case-study themes, while individual accounts were retained as reported experiences and were not generalized to the entire Altadena population.

3.6 Regulatory and Code Analysis

Applicable Codes and Standards. At the time of the January 7, 2025 Eaton Fire, Altadena, as an unincorporated community of Los Angeles County, was subject to the 2022 California Building Standards Code (Title 24), as adopted and amended by Los Angeles County, including the 2022 California Building Code (CBC), 2022 California Residential Code (CRC), and applicable California accessibility and wildfire-exposure provisions, together with the 2023 Los Angeles County Fire Code (Title 32). The 2022 California Building Standards Code became effective statewide on January 1, 2023, while the 2023 Los Angeles County Fire Code was effective January 11, 2024.

- For purposes of this study, regulatory analysis therefore focuses on the California codes and Los Angeles County amendments legally applicable on the date of the fire.

The international model codes, including the IBC, IFC, and IWUIC, are referenced only where incorporated into applicable California or County requirements or used as comparative WUI resilience guidance; they are not independently treated as governing codes for the Eaton Fire. The 2010 ADA Standards for Accessible Design are considered where federal accessibility requirements are applicable.

3.7 Triangulation, Evidence Classification, and Limitations

GIS observations, agency reports, media investigations, survivor accounts, field observations, planning documents, and regulatory evidence were initially considered according to their source type and then compared through source triangulation. Findings supported by multiple independent evidence streams or primary official records were treated as corroborated case-study evidence. Individual accounts that could not be independently corroborated were retained as reported experiences rather than generalized findings. Evidence was classified as spatially observed, officially documented, documentary or participant-reported, regulatory interpretation, or conceptual–semi-empirical

model output. Conflicting accounts were not averaged or converted into numerical values unless independently supported by quantitative data.

4. Findings & Analysis

4.1 Road Network and Evacuation Constraints

The Altadena area is characterized by limited east–west connectivity and reliance on a small number of arterial roads, including canyon access routes (Cova, 1999)⁴; (Altadena Town Council, 2025)⁵.

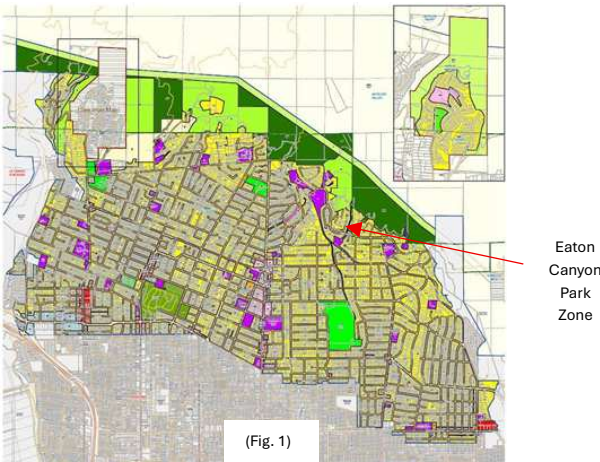


Figure 1 illustrates the overall land-use and development pattern of Altadena, showing the spatial relationship between residential neighborhoods, parks, institutional facilities, transportation corridors, and the foothill open-space areas along the southern edge of the San Gabriel Mountains. The figure-map demonstrates how large portions of Altadena's residential development are located immediately adjacent to vegetated foothill and wildland areas (light and dark green), creating a direct wildland–urban interface (WUI). From a wildfire perspective, this pattern increases community exposure because residential structures, infrastructure, and evacuation routes are situated near continuous vegetation fuels that can facilitate wildfire intrusion into developed areas.

Chart 1. Altadena Land Use vs Wildfire Exposure & Evacuation Capacity

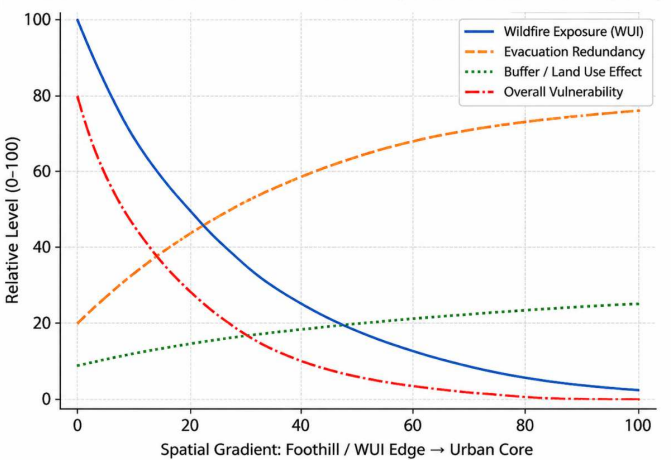


Chart 1 conceptually illustrates the spatial relationship between wildfire exposure, evacuation redundancy, land-use buffering, and overall community vulnerability across the Altadena wildland–urban interface (WUI). The chart corresponds directly to figure 1, which shows residential development extending northward toward the San Gabriel Mountain foothills and adjacent open-space areas. As development approaches the WUI boundary, wildfire exposure generally increases due to closer proximity to vegetative fuels, steeper terrain, and reduced separation between structures and wildland areas.

Photos 2 & 3 capture the real-world



manifestation where communities located closest to vegetated foothill areas

experienced the greatest exposure while simultaneously facing increased evacuation challenges.

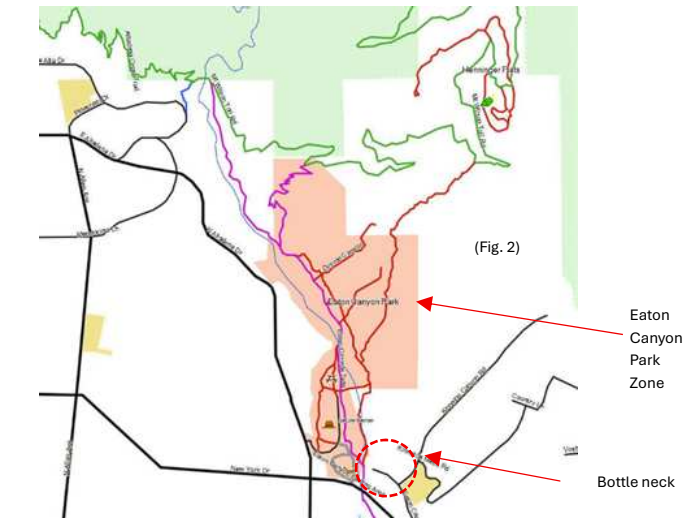


Figure 2 provides a localized focused view of the Eaton Canyon Park Zone, illustrating the canyon system, trail network, access roads, and foothill terrain directly north of Altadena. The light orange shaded area appears to correspond to a topographically constrained foothill neighborhood adjacent to Eaton Canyon. From a transportation-network perspective, this area exhibits characteristics of a potential evacuation bottleneck, where multiple residential streets converge toward a limited number of southbound access routes. The combination of constrained roadway connectivity, canyon topography, and limited route redundancy may increase evacuation vulnerability during rapidly developing wildfire.

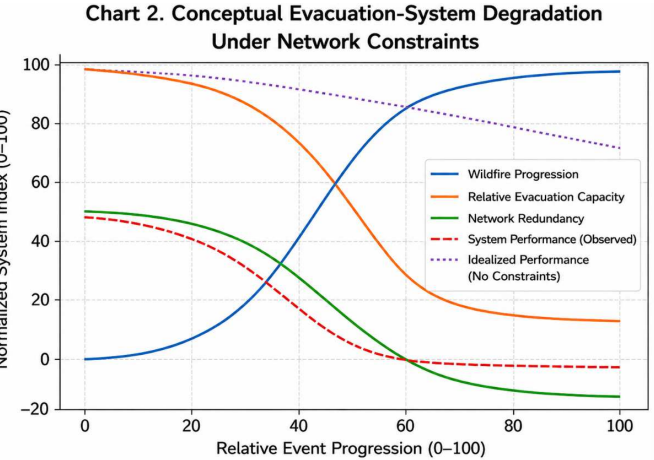


Chart 2 conceptually illustrates how evacuation-system performance may deteriorate as wildfire progression increases within a constrained transportation network. The chart relates to Figure 2, which depicts canyon-based roadway conditions, limited route alternatives, and topographic constraints associated with the Eaton Canyon foothill environment. The model is characterized as conceptual–semi-empirical because the direction and relative behavior of the curves are informed by documented wildfire observations, evacuation studies, roadway analyses, survivor and media accounts, and emergency-response information. The normalized values are illustrative and do not represent measured roadway capacity, traffic volume, or calibrated evacuation performance.



Photos 4 & 5 provide visual evidence of the transportation and evacuation challenges associated with canyon-based WUI communities, where

constrained road networks, limited route alternatives, and rapidly changing fire behavior can contribute to evacuation bottlenecks, vehicle abandonment, and increased life-safety risk.

4.2 Fire Spread and Topographic Influence



As shown in figure 3, the fire extended beyond undeveloped wildland areas and into residential neighborhoods located along the wildland–urban interface (WUI), illustrating the close spatial relationship between vegetated foothill landscapes and community development.

The substantial overlap between the fire perimeter and developed areas suggests that residential communities adjacent to continuous wildland fuels may experience elevated wildfire exposure during large WUI fire events. Similar observations have been reported in previous wildfire studies, which identified WUI development patterns, fuel continuity, and proximity to vegetated landscapes as important factors influencing wildfire vulnerability, structure exposure, and potential loss (Radeloff²; Syphard³; (IBHS, 2025)⁶.

Figure 3 illustrates the spatial extent of the Eaton Fire in relation to the Altadena community and the San Gabriel Mountain foothills. The fire perimeter (orange) highlights the direct interface between mountainous wildland areas and residential development, demonstrating how large portions of Altadena are situated within a high-exposure WUI environment.

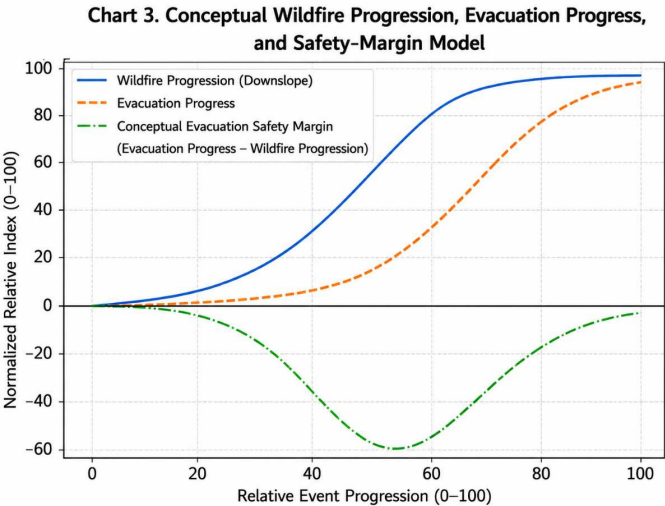


Chart 3 presents a conceptual–semi-empirical representation of the relationship between wildfire progression, evacuation progress, and the available evacuation safety margin during a rapidly evolving WUI wildfire event. The blue curve illustrates the relative progression of wildfire conditions, while the orange curve represents the relative progression of evacuation activities. The green curve depicts the conceptual evacuation safety margin, defined as the difference between wildfire advancement and evacuation completion over time.

Figure 3 and Chart 3 collectively suggest that when wildfire progression outpaces evacuation progress, the conceptual safety margin may decrease, potentially reducing the time available for residents to evacuate. This relationship is particularly relevant to WUI communities where evacuation may be affected by roadway constraints, topography, emergency communication,

and population-response characteristics. As the conceptual safety margin narrows, evacuation challenges may become more pronounced for populations requiring additional warning, transportation, mobility, or assisted-evacuation time. The safety-margin curve represents a normalized conceptual relationship and should not be interpreted as a measured temporal, probabilistic, or population-level safety margin.

4.3 Emergency Communication and Alert Systems

Emergency communication and alert systems are critical components of wildfire emergency management because they support timely evacuation decision-making, enhance situational awareness, and help reduce life-safety risk. In rapidly evolving wildland–urban interface (WUI) wildfire events, the effectiveness of emergency communication depends not only on the speed of alert dissemination but also on message clarity, consistency, geographic accuracy, and coordination across multiple communication platforms (Mileti & Sorensen, 1990)⁷.

Public reports and post-event assessments associated with the Altadena Fire suggest that variations in alert timing, message distribution, and evacuation communication may have influenced evacuation response behavior in some affected areas.

These observations highlight the importance of integrated emergency communication systems capable of delivering timely, geographically targeted, and clearly worded evacuation instructions through multiple coordinated channels. Previous emergency-management research has shown that delays in warning dissemination, inconsistent messaging, and fragmented communication can reduce public understanding of risk, delay protective action, and diminish overall evacuation effectiveness (FEMA, 2018)⁸; (NFPA, 2024)⁹.

Photo 6 illustrates a wireless emergency alert received during the Eaton Fire. Mobile emergency notification systems provide an important mechanism for communicating evacuation warnings and situational information to at-risk populations.



However, the effectiveness of these systems depends on the timely delivery of alerts, the clarity of evacuation instructions, and the consistency of information provided across communication platforms. In rapidly developing WUI wildfire environments, where wildfire progression may outpace evacuation activities, even modest delays in warning dissemination or public interpretation may reduce the available evacuation window and increase evacuation challenges, particularly for vulnerable populations requiring additional time or assistance.

Official after-action reports and investigative analyses of the Eaton Fire, documented concerns regarding the timing, geographic distribution, and coordination of evacuation alerts in portions of Altadena. Some reports identified substantial differences in warning timing among affected areas, potentially reducing the evacuation window available to certain resident (McChrystal Group, 2025)¹⁰; (The Wall Street Journal, 2025)¹². These findings are interpreted according to the geographic areas and timelines documented by the respective sources and are not intended to imply that all Altadena residents experienced identical warning conditions.

Reports further identified unclear messaging, fragmented communication systems, and lack of inter-agency coordination as key contributors to reduced evacuation effectiveness and increased fatality risk.

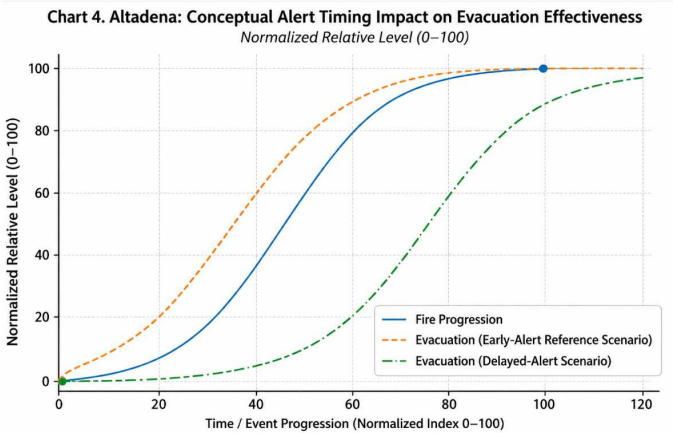


Chart 4 conceptually illustrates the relationship between wildfire progression, emergency-alert timing, and evacuation effectiveness during the Altadena (Eaton) Fire. When interpreted together with the Eaton Fire perimeter map (Figure 3), the model suggests that communities within or near the advancing wildland–urban interface (WUI) fire zone may have faced increasingly constrained evacuation opportunities as wildfire conditions expanded into residential areas.

The early-alert reference scenario illustrates how earlier warning could provide a greater evacuation window, whereas the delayed-alert scenario illustrates how later warnings may reduce the available margin for evacuation as fire conditions progress. Values are normalized conceptual indices (0–100) used for comparative visualization and do not represent measured population percentages, probabilities, or validated evacuation-performance metrics.

4.4 Regulatory and Emergency-System Findings

The Eaton Fire findings indicate that evacuation performance depended on the interaction of multiple regulatory and emergency-management systems rather than on building or fire-code provisions alone.

At the time of the fire, Altadena was subject to applicable California and Los Angeles County building, fire, accessibility, and emergency-response requirements. However, the observed evacuation challenges indicate that requirements addressing individual components of life safety do not necessarily ensure coordinated community-scale performance during a rapidly evolving WUI wildfire.

Documented concerns involving emergency communication, evacuation coordination, roadway constraints, accessibility, and assistance for vulnerable populations demonstrate the importance of integrating regulatory requirements with transportation planning, emergency management, and accessible evacuation procedures.

These findings are treated as system-level observations and do not, by themselves, establish individual code violations.

4.5 Accessibility Barriers

Accessibility-related challenges emerged as an important factor influencing evacuation conditions during the Altadena Fire, particularly among older adults, individuals with disabilities, medically vulnerable residents, and households requiring assistance.

In rapidly evolving wildland–urban interface (WUI) wildfire events, evacuation effectiveness may be influenced not only by wildfire behavior and transportation infrastructure but also by the ability of individuals to receive warnings, access transportation, navigate evacuation routes, and obtain necessary assistance.

Previous evacuation research has shown that mobility limitations, dependence on caregivers, delayed risk perception, and medical-support needs may increase evacuation time requirements and reduce evacuation flexibility during emergency events (Kuligowski, 2013)¹³; (Lovreglio et al., 2016)¹⁴.



Photos 7 and 8 illustrate human and physical consequences associated with wildfire impacts in WUI communities.

- Photo 8 depicts an assisted evacuation under smoky, low-visibility conditions, while
- Photo 7 shows a residential structure actively involved in fire.

The images also underscore the potential vulnerability of populations requiring additional evacuation time or assistance.

As wildfire conditions intensify and evacuation opportunities become increasingly constrained, accessibility-related factors may have a greater influence on evacuation outcomes.

These observations are consistent with previous research suggesting that vulnerable populations often experience disproportionate evacuation challenges during fast-moving wildfire events, particularly in communities characterized by limited route redundancy, high wildfire exposure, and rapidly deteriorating environmental conditions (Kuligowski)¹³; (Lovreglio)¹⁴.

Table 1. Documentary Survivor and Media Accounts Related to Accessibility Barriers During the Eaton Fire

No.	Documentary Source / Case	Accessibility Barrier	Key Findings
1	Sharp (2025) ¹⁵ ; Stone (2025) ¹⁶ – Anthony Mitchell Sr. & Justin Mitchell evacuation failure case	Wheelchair evacuation limitations	Anthony Mitchell Sr. and his son Justin, both wheelchair users, reportedly requested evacuation assistance during the Eaton Fire but were unable to evacuate safely in time. Their deaths became a significant example of the vulnerability of mobility-impaired residents during delayed evacuation conditions.
2	Sharp (2025) ¹⁵ – Elderly and disabled evacuation trauma in Altadena	Lack of alerts and transportation assistance	Interviews documented elderly residents lacking access to mobile alerts, transportation, and coordinated evacuation assistance. Shelter occupants described confusion, delayed awareness, and difficulties evacuating during rapidly changing fire.
3	Toohey (2025) ¹⁷ – Mirador senior housing residents stranded during Eaton Fire	Insufficient support for medically vulnerable residents	Residents of a low-income senior housing complex reported limited evacuation assistance for disabled and medically vulnerable occupants. Witnesses stated that many residents “saved themselves” due to inadequate coordinated support.
4	Direct Relief, 2025 ¹⁷ – Rescue workers evacuating wheelchair users through flames	Hazardous assisted evacuation conditions	Search-and-rescue responders described evacuating wheelchair users through dense smoke and active fire conditions. Accounts highlighted blocked roads, poor visibility, and rapidly deteriorating conditions that complicated evacuation efforts.
5	Washington Post, 2025 ¹⁸ – Delayed alerts and vulnerable populations in west Altadena	Delayed warnings and communication failures	Residents west of Lake Avenue reported receiving little or no official evacuation guidance for hours. Elderly and disabled residents struggled to evacuate amid power outages, communication breakdowns, and lack of transportation support.
6	Wall Street Journal, 2025 ¹⁹ – Communication failures affecting the elderly and disabled residents	Language, mobility, and notification barriers	Families described language barriers, mobility impairments, and delayed emergency notifications that prevented vulnerable residents from evacuating safely. Reports noted that many fatalities involved elderly or disabled individuals.
7	AP News, 2025 ²⁰ – Investigation into delayed evacuation orders and disability impacts	Disparities in emergency response	Survivor advocacy groups and residents raised concerns that delayed evacuation orders disproportionately affected older adults and disabled residents in west Altadena. The investigation referenced disability-related inequities in emergency response operations.
8	ABC News, 2025 ¹⁶ – Disability-specific evacuation barriers during California wildfires	Inaccessible evacuation infrastructure	Disability advocates discussed transportation dependence, medical equipment needs, medication planning, and the lack of accessible evacuation infrastructure for disabled residents during wildfire emergencies.

Table 1 presents a qualitative synthesis of documented accessibility-related challenges reported during the Altadena Fire. Drawing from survivor accounts, media investigations, emergency response reports, and disability advocacy perspectives, the table identifies recurring themes associated with evacuation difficulties experienced by elderly individuals, persons with disabilities, and medically vulnerable populations.

The reported barriers include mobility limitations, transportation dependence, delayed emergency notifications, communication failures, caregiver reliance, language barriers, and insufficient coordinated evacuation assistance. The table organizes diverse qualitative evidence into identifiable categories of accessibility challenges.

The findings suggest that evacuation barriers extended beyond physical mobility constraints and included broader issues related to communication access, transportation availability, medical-support requirements, and emergency-management coordination. The recurrence of similar observations across multiple independent sources indicates that accessibility-related factors may have influenced evacuation conditions during the wildfire. This table should be interpreted as a qualitative thematic analysis rather than a quantitative assessment of evacuation performance.

The findings are derived primarily from publicly available interviews, survivor narratives, media reports, and preliminary investigations rather than validated operational datasets.

4.6 Zoning and Planning Deficiencies

The Eaton Fire highlighted land-use and planning challenges associated with established development in high-risk wildland–urban interface (WUI) environments. As illustrated by the Eaton Fire perimeter (Figure 6), residential neighborhoods extend toward the San Gabriel Mountain foothills and areas of wildland vegetation, creating interfaces where developed areas may be exposed to wildfire originating in adjacent landscapes. The Eaton Fire originated near Altadena Drive and Midwick Drive and ultimately burned approximately 14,021 acres.

Post-fire investigation provides additional evidence that wildfire vulnerability at the community scale depends on more than individual building characteristics. IBHS field investigations of the Eaton and Palisades fires found that structure spacing, connective fuels—including vegetation—and building characteristics interacted to influence damage outcomes.

The findings indicate that greater spacing and lower connective-fuel density improved the likelihood of structures avoiding damage, while vegetation and other combustible materials near structures could provide pathways for fire propagation.



Photos 10 and 11 document extensive structural destruction within developed residential areas affected by the Eaton Fire. The observed damage illustrates the potential for community-scale fire propagation where structures, vegetation, and other combustible materials are closely interconnected within the WUI environment.

These findings support consideration of defensible space and fuel management at both property and community scales. Following the 2025 fires, IBHS recommended extending wildfire-resistant construction and Zone 0 measures within the Eaton Fire footprint, maximizing structure separation where feasible, and establishing and maintaining fuel breaks along the perimeter of communities in high-hazard areas. Such recommendations suggest that community-scale WUI resilience requires coordinated land-use planning, vegetation management, building mitigation, and fuel-buffer strategies rather than reliance solely on individual-property measures.

Previous wildfire studies have identified fuel continuity and proximity to wildland vegetation as important factors influencing wildfire exposure and structure loss within WUI communities (Syphard³; (IBHS)⁶.

Table 2: Factors Influencing Wildfire Vulnerability and Society Resilience

Factor	Observed Condition	Impact
Land-Use Patterns	Concentration adjacent to wildfire-prone areas.	Increased exposure to wildfire hazards.
Fuel Continuity	Continuous vegetation to residential areas.	Wildfire spread and ember intrusion into urban areas.
Topographic Conditions	Steep slopes influenced evacuation access.	Fire spread and constrained evacuation opportunities.
Infrastructure Capacity	Roadway limited access points.	Congestion and evacuation delays during emergency.
Emergency Communication	Delayed, fragmented, inconsistent warnings.	Reduced available evacuation time.

Accessibility Considerations	Vulnerable experienced evacuation challenges.	Evacuation complexity and vulnerability conditions.
Evacuation Planning	constrained transportation networks.	Exceeded normal transportation capacity.
Emergency Management	Operated under extreme wildfire conditions.	Effectiveness depends on multiple combined systems.
Wildfire Risk Assessment	Evaluated alone from transport & accessibility.	Interdependence has not been fully addressed.
Community Resilience	Multiple factors rather than a single system.	Performance depended on the collective effectiveness.

Table 2 summarizes the interdependent factors identified through the case-study analysis as influencing wildfire vulnerability and community resilience. The table illustrates how land-use patterns, fuel continuity, topography, infrastructure capacity, emergency communication, accessibility, evacuation planning, and emergency management may interact during a WUI wildfire. The relationships are qualitative and should not be interpreted as quantified estimates of risk reduction or system performance..

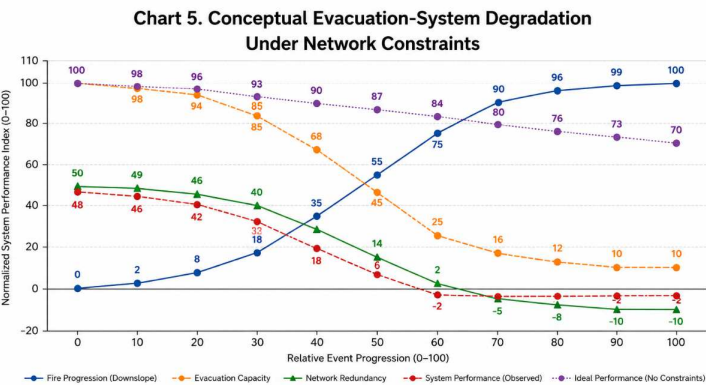


Chart 5 conceptually illustrates how evacuation-system performance may deteriorate as wildfire progression increases within a constrained transportation network. As wildfire conditions intensify, relative evacuation capacity and network redundancy decline, contributing to reduced overall system performance compared with an idealized unconstrained condition. Values are normalized conceptual–semi-empirical indices (0–100) used for comparative visualization and do not represent measured roadway capacities, probabilities, or validated predictive outcomes.

The joint statement, issued by AltadenaWILD and the Chaney Trail Corridor Project 2025²¹, expresses strong support for the proposed West San Gabriel Valley Area Plan (WSGVAP) and its associated zoning and land-use updates affecting Altadena and the foothill communities, was developed through an extensive public outreach process and is designed to guide future growth while reducing environmental and wildfire-related risks.

A central theme of the statement is that the WSGVAP seeks to direct future development away from high-hazard areas, including wildfire-prone foothills, landslide-prone slopes, flood-risk zones, and environmentally sensitive lands. The plan emphasizes limiting expansion of the wildland–urban interface (WUI), protecting significant ecological areas, preserving habitat connectivity, and minimizing habitat fragmentation.

Table 3: West San Gabriel Valley Area Plan (WSGVAP) Objectives

WSGVAP	Primary Objective	Outcome
Hazard-Avoidance Development	Direct future growth away from wildfire-prone areas.	Reduce development to natural hazards.
WUI Growth Management	Limit expansion of the wildland–urban interface.	Reduce exposure to WUI hazards.
Ecological Area Protection	Protect major ecological and sensitive lands.	Reduce environmental degradation.
Habitat Preservation	Maintain interconnected wildlife corridors	Support ecosystem health and biodiversity.

Habitat Fragmentation	Minimize the fragmentation of natural landscapes.	Preserve open-space functions.
Urban Growth Concentration	Focus on urbanized areas & transportation corridors.	Improve infrastructure efficiency impacts.
Open-Space Preservation	Preserve and expand open-space resources.	Maintain environmental quality resilience.
Climate & Hazard Adaptation	Incorporate climate-related risks into planning.	Promote long-term sustainability.
Public and Community Action	Utilize extensive public outreach in planning.	Improve transparency & public involvement.
Integrated Planning	Balance green protection with public needs.	Support sustainable growth w/ less hazard.

As per table 3 (Los Angeles County Department of Regional Planning, 2023)¹⁹, the WSGVAP promotes a hazard-informed planning approach that seeks to limit future development in wildfire-prone foothill environments, reduce expansion of the wildland–urban interface (WUI), preserve ecological resources, and concentrate growth within existing urbanized areas. Many of these objectives directly address vulnerabilities observed during the Altadena (Eaton) Fire, including wildfire exposure, fuel continuity, development adjacent to foothill vegetation, and long-term community resilience.

4.6 Regulatory Integration and Community-Scale Resilience Gap

The regulatory analysis indicates that building, fire, accessibility, land-use, transportation, and emergency-management requirements address different components of life safety, but their separate application does not necessarily establish an integrated community-scale wildfire evacuation system. For the Eaton Fire, regulatory conclusions were based on requirements applicable in California and unincorporated Los Angeles County on January 7, 2025. Model codes and later standards not independently applicable to the event were considered only as comparative resilience benchmarks and were not used to establish regulatory violations.

- California and Los Angeles County Building Requirements:

At the time of the Eaton Fire, building construction in unincorporated Altadena was governed by the: 2022 California Building Code (CBC), (California Building Standards Commission, 2022)²¹, as adopted and amended by the 2023 Los Angeles County Building Code, Title 26 (County of Los Angeles, 2023)²⁴, together with the 2022 California Residential Code as adopted by Los Angeles County Title 30, where applicable. These codes address construction, occupancy, fire-resistance, means of egress, accessibility, and other building-level life-safety requirements. However, the Eaton Fire involved community-scale conditions extending beyond individual buildings, including wildfire intrusion, roadway-network constraints, evacuation timing, emergency communication, and accessibility. Accordingly, compliance with building-level requirements alone does not necessarily establish adequate community-scale evacuation performance.

- Wildfire-Exposure Requirements:

The 2022 California Building Code Chapter 7A, as amended by Los Angeles County, establishes requirements for materials and construction methods intended to improve resistance to exterior wildfire exposure in designated WUI and Fire Hazard Severity Zone conditions. Los Angeles County’s version of Chapter 7A applies more broadly to new buildings and specified additions, alterations, or repairs within applicable WUI Fire Areas.

These provisions address ignition-resistant construction, roofing, vents, exterior coverings, windows and doors, decking, and related wildfire-exposure features. Their applicability depends on the location, scope, age, and regulatory status of a particular building; therefore, the presence of older or more vulnerable structures within the Eaton Fire area should not, by itself, be characterized as a code violation.

- Los Angeles County Fire Code:

Fire-protection and emergency-access requirements applicable at the time of the fire were governed by the 2023 Los Angeles County Fire Code, Title 32, which was effective January 11, 2024. These provisions address matters

including fire department access, fire apparatus roads, fire-protection systems, operational fire safety, and emergency-response functions. The Eaton Fire nevertheless illustrates that community evacuation and incoming emergency-response traffic can place simultaneous demands on a constrained roadway network. Such system-level conditions extend beyond the performance of individual fire-access provisions and highlight the importance of integrating fire-code requirements with transportation and evacuation planning.

• Accessibility Requirements:

Federal accessibility requirements applicable to state and local government services and public accommodations are established through the Americans with Disabilities Act (ADA) and the 2010 ADA Standards for Accessible Design, together with applicable California accessibility provisions. The 2010 Standards establish enforceable accessibility requirements for new construction and alterations within their respective Title II and Title III scopes (U.S. Department of Justice, 2010)²⁰.

However, accessible wildfire evacuation also depends on factors extending beyond architectural accessibility, including accessible emergency communication, transportation, shelters, caregiver support, medical-equipment accommodations, and coordinated evacuation assistance.

• Comparative WUI Standards:

The 2021 International Wildland–Urban Interface Code (IWUIC) may provide useful comparative guidance concerning vegetation management, defensible space, ignition-resistant construction, and community wildfire mitigation (IWUIC, ICC, 2021)²⁶; however, it should not be treated as an independently applicable governing code for the January 2025 Eaton Fire unless specific adoption applicable to the site and date is established. In this study, IWUIC provisions are therefore used only as comparative resilience benchmarks where appropriate.

• Overall Finding:

The findings indicate a potential gap not necessarily in compliance with any single code, but in the integration of otherwise separate regulatory and planning systems. Building, fire, accessibility, transportation, land-use, and emergency-management requirements each address important components of life safety; however, effective WUI evacuation requires these systems to function collectively under rapidly evolving disaster conditions. Accordingly, the observations discussed in this study are treated as system-level resilience findings and do not, by themselves, establish individual regulatory violations.

Table 4. Integrated Community-Scale Resilience Framework

Regulatory / Planning Domain	Traditional Focus	Observed System-Level Condition
CA/LA County Fire Requirements	Fire access and emergency response	Evacuation and response competed for road access
Transportation Planning	Road capacity and connectivity	Congestion and limited route redundancy
Emergency Communication	Public alerts and warnings	Variable alert timing and coverage
Federal/CA Accessibility Requirements	Accessibility and equal access	Added challenges for vulnerable populations
Evacuation Planning	Procedures and coordination	Infrastructure and communication constraints
Land-Use / WUI Planning	Development and wildfire exposure	Development adjacent to wildfire-prone areas
Integrated Community Resilience	Multiple separate systems	Limited system-wide integration

Table 4 illustrates that wildfire-evacuation performance depends on the interaction of multiple regulatory, planning, accessibility, transportation, communication, and emergency-management systems. The observed conditions suggest a need for greater system-wide integration and do not, by

themselves, establish noncompliance with any individual code or regulatory requirement.

Table 4 and Chart 6 conceptually compare the scope of regulatory and planning frameworks with documented wildfire-evacuation system conditions during the Eaton Fire. The comparison illustrates a potential coordination gap among independently administered fire protection, transportation, emergency communication, accessibility, evacuation, and land-use systems rather than measured differences in regulatory compliance or evacuation performance.

Chart 6. Conceptual Comparison of Regulatory Framework Coverage and Wildfire–Evacuation System Performance

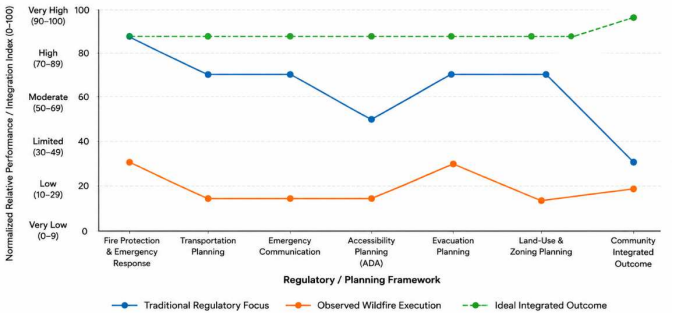


Chart 6 conceptually contrasts the scope of regulatory and planning frameworks with observed wildfire-evacuation conditions across key domains. The Ideal Integrated Outcome represents an aspirational benchmark in which these domains function as a coordinated, system-wide life-safety network. Values are normalized indices (0–100) for comparative visualization only and do not represent measured compliance rates, probabilities, or validated performance metrics.

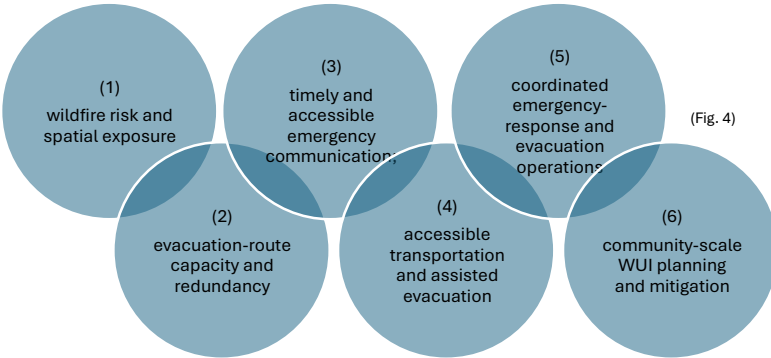
The Ideal Integrated Outcome represents an aspirational benchmark in which all domains function as a coordinated, system-wide life-safety network. Values are normalized indices (0–100) for comparative visualization only and do not represent measured compliance rates, probabilities, or validated performance metrics.

The most important feature of the figure is the Ideal Integrated Outcome line, which represents a coordinated, system-wide approach in which all regulatory disciplines operate collectively rather than independently.

The Altadena (Eaton) Fire demonstrated that compliance with individual codes and regulations may not be sufficient to ensure community safety during large WUI wildfire events. Future resilience efforts may benefit from a performance-based, community-scale approach that evaluates the interaction among wildfire exposure, transportation capacity, emergency communication reliability, accessibility needs, and evacuation effectiveness. Such integration may help bridge the gap between regulatory compliance and real-world life-safety outcomes during future wildfire emergencies.

4.7 Proposed Accessible Wildfire Evacuation Model (AWEM)

Based on the combined findings of this study, an Accessible Wildfire Evacuation Model (AWEM) is proposed as a conceptual framework for integrating wildfire exposure, transportation-network capacity, emergency communication, accessibility, evacuation planning, and emergency-response coordination at the community scale. Rather than treating these elements as independent regulatory or operational systems, AWEM considers their interdependence during rapidly evolving WUI wildfire conditions.



(Fig. 4)

Figure 4. The AWEM model emphasizes six interconnected components:

1. Wildfire Risk and Spatial Exposure:

Evaluates the spatial relationship among wildfire hazards, WUI boundaries, topography, vegetation, development patterns, and vulnerable populations. This component identifies areas where fire exposure and physical conditions may create increased evacuation risk.

2. Evacuation-Route Capacity and Redundancy:

Examines roadway connectivity, bottlenecks, dead-end conditions, alternative routes, and the interaction between outbound evacuation traffic and incoming emergency vehicles. Multiple viable evacuation routes can reduce dependence on a single constrained corridor.

3. Timely and Accessible Emergency Communication:

Emphasizes early, geographically targeted, redundant, and understandable emergency warnings delivered through multiple communication methods. Alerts should also be accessible to people with sensory, cognitive, language, or technology-related communication barriers.

4. Accessible Transportation and Assisted Evacuation:

Addresses the evacuation needs of people who cannot independently use conventional transportation or evacuation routes. Planning should include accessible vehicles, mobility assistance, caregiver coordination, medical-support needs, and additional evacuation time for vulnerable populations.

5. Coordinated Emergency-Response and Evacuation Operations:

Integrates fire, law enforcement, transportation, emergency management, utilities, accessibility services, and community organizations within a coordinated operational framework. Particular attention should be given to maintaining evacuation movement while emergency responders simultaneously enter affected areas.

6. Community-Scale WUI Planning and Mitigation:

Extends wildfire resilience beyond individual properties by integrating land-use planning, defensible space, vegetation and fuel management, ignition-resistant construction, infrastructure, and evacuation planning. The objective is to reduce wildfire exposure while improving community-wide evacuation resilience. Together, these six components form an interconnected life-safety framework in which wildfire mitigation, evacuation infrastructure, accessibility, communication, and emergency response are evaluated collectively rather than as independent systems.

AWEM is proposed as a conceptual planning and evaluation framework rather than a validated predictive model or regulatory standard. Its purpose is to identify potential gaps between independently administered systems and support more integrated, accessibility-centered wildfire evacuation planning. Future research should validate and refine the framework using empirical evacuation timelines, transportation and mobility data, emergency-alert records, accessibility assessments, and additional WUI wildfire case studies.

- The principal contribution of this study is therefore the identification of wildfire evacuation as an integrated community-scale life-safety problem rather than a collection of independent building, fire, transportation, accessibility, and emergency-management functions.

The Eaton Fire case demonstrates that individually administered systems may provide important protections within their respective scopes while still leaving coordination gaps when required to operate simultaneously during a rapidly evolving WUI wildfire. AWEM translates this finding into a conceptual framework that places accessibility, evacuation infrastructure, emergency communication, wildfire exposure, and emergency-response coordination within a single community-scale resilience model. This framework provides a basis for future empirical evaluation and for developing more integrated and equitable WUI evacuation strategies.

5. Conclusion

The 2025 Eaton Fire demonstrates that wildfire life safety in established wildland-urban interface (WUI) communities depend on the interaction of multiple physical, social, regulatory, and emergency-management systems. The Altadena case indicates that roadway configuration, limited evacuation-route

redundancy, emergency communication, accessibility needs, land-use patterns, wildfire exposure, and emergency-response operations can interact during a rapidly evolving wildfire and influence community evacuation conditions.

The findings also highlight particular challenges for older adults, people with disabilities, medically dependent residents, and others requiring additional warning, transportation, mobility assistance, or evacuation support. Effective wildfire preparedness therefore requires accessibility to be incorporated into emergency communication, transportation, evacuation procedures, shelters, and community-level response planning rather than addressed solely through building-level accessibility provisions.

The regulatory analysis further indicates that applicable California and Los Angeles County building, fire, accessibility, land-use, transportation, and emergency-management requirements provide important life-safety protections within their respective scopes. However, compliance within individual regulatory domains does not necessarily ensure coordinated community-scale performance during a rapidly evolving WUI disaster. Contemporary WUI and accessibility standards may provide useful comparative guidance, but standards not independently applicable to the 2025 Eaton Fire were not used in this study to establish regulatory violations.

Based on the combined spatial, documentary, accessibility, regulatory, and conceptual-semi-empirical analysis, the following recommendations are proposed:

1. Integrate wildfire evacuation into community-scale WUI planning. Evacuation capacity, route redundancy, wildfire exposure, land use, and emergency access should be evaluated collectively during community planning and resilience assessments.
2. Improve evacuation-route redundancy and network resilience. WUI communities should identify roadway bottlenecks, constrained intersections, dead-end conditions, and alternative evacuation routes before wildfire emergencies occur.
3. Strengthen emergency warning and communication systems. Emergency alerts should provide timely, geographically targeted, redundant, and accessible information through multiple communication methods.
4. Integrate accessibility into evacuation planning. Emergency plans should address accessible transportation, mobility assistance, medical needs, caregiver coordination, accessible shelters, and additional evacuation time for populations requiring assistance.
5. Expand community-scale wildfire mitigation. Defensible space, vegetation management, fuel reduction, structure separation where feasible, and ignition-resistant construction should be coordinated at both individual-property and neighborhood scales.
6. Improve interagency coordination. Fire protection, transportation, law enforcement, emergency management, accessibility services, utilities, and community organizations should establish coordinated evacuation protocols and conduct WUI-specific exercises.
7. Advance integrated regulatory and planning approaches. Building, fire, accessibility, transportation, land-use, and emergency-management requirements should be evaluated as interconnected components of community resilience rather than as independent regulatory systems.

The proposed Accessible Wildfire Evacuation Model (AWEM) provides a framework for integrating these elements into a coordinated community-scale approach centered on equitable evacuation and life safety. The conceptual-semi-empirical models presented in this study should be interpreted as normalized explanatory tools rather than measured population-level evacuation rates, roadway capacities, regulatory-compliance percentages, probabilities, or validated predictive outcomes. Future applications of AWEM should therefore include empirical validation using detailed evacuation timelines, traffic and mobility data, alert records, accessibility assessments, and additional wildfire case studies.

Overall, the Eaton Fire demonstrates that resilient WUI communities require more than individual building or fire-safety measures. Effective wildfire life

safety depends on the coordinated performance of the built environment, transportation network, emergency communication, accessibility systems, wildfire mitigation, and emergency management before and during a disaster.

6. Future Research

Future research should build upon the limitations and findings of this study by empirically testing the relationships among wildfire exposure, evacuation infrastructure, accessibility, emergency communication, and community-scale resilience.

6.1 Evacuation and Spatial Modeling

Future studies should integrate detailed roadway-network modeling, traffic simulation, wildfire progression, and evacuation timelines to quantify route capacity, redundancy, congestion, and emergency-access constraints under different WUI wildfire scenarios.

6.2 Accessibility and Vulnerable Populations

Additional research should evaluate evacuation experiences of older adults, people with disabilities, medically dependent residents, and others requiring assistance. Particular attention should be given to accessible warnings, transportation, caregiver support, shelters, and measurable accessibility-performance indicators.

6.3 AWEM Validation and Comparative Analysis

The proposed Accessible Wildfire Evacuation Model (AWEM) should be tested and refined using empirical data, evacuation simulations, field exercises, and comparative WUI case studies. Comparison of the 2025 Eaton Fire with events such as the 2023 Lahaina Fire and 2018 Camp Fire may help evaluate the model's applicability across different geographic and regulatory environments.

6.4 Integrated Resilience and Emerging Technologies

Future research should examine how land-use planning, transportation, wildfire mitigation, accessibility, emergency communication, and emergency management can be better integrated at the community scale. Real-time GIS, remote sensing, artificial intelligence, and predictive evacuation modeling should also be evaluated for their potential to improve situational awareness, evacuation routing, and emergency decision-making.

Limitations

This study is limited by the availability of post-disaster datasets, evolving official investigations, reliance on publicly available survivor and eyewitness accounts, media documentation, field observations, and conceptual–semi-empirical modeling.

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Declarations

Funding Declaration:

This research received no specific grant, financial support, funding, or sponsorship from any public, commercial, governmental, institutional, or not-for-profit funding agency. The research was conducted independently by the author as part of ongoing academic and professional research activities.

Clinical trial number (not applicable):

This study did not involve a clinical trial, medical intervention, patient treatment protocol, or any form of clinical research requiring trial registration.

Ethics, Consent to Participate, and Consent to Publish:

This study did not involve clinical research, medical experimentation, human-subject testing, or the collection of personally identifiable information requiring formal institutional ethics review. The research was based on publicly available government reports, media sources, published documents, field observations, and voluntary interviews conducted for educational and research purposes.

No confidential or protected personal information was collected or disclosed.

- Ethics approval: not applicable.
- Consent to participate not applicable.

- Consent for publication: not applicable.

AI-assisted Declaration:

During the preparation of this work, the author used ChatGPT solely for spelling and grammar review of the manuscript content. The author reviewed and edited the output as necessary and takes full responsibility for the published article content.

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- Photo locations are identified in the captions based on source documentation or field records; where a precise location could not be independently verified, the caption identifies only the geographic area supported by the available evidence. Photographs were used as supporting visual evidence and were not used to infer conditions beyond those directly observable or documented by the cited source.

List of Abbreviations

Abbreviation	Full Term
ADA	Americans with Disabilities Act
AI	Artificial Intelligence
AWEM	Accessible Wildfire Evacuation Model
CAL FIRE	California Department of Forestry and Fire Protection
CBC	California Building Code
CRC	California Residential Code
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
IBC	International Building Code
IBHS	Insurance Institute for Business & Home Safety
IFC	International Fire Code
IPAWS	Integrated Public Alert and Warning System
IWUIC	International Wildland–Urban Interface Code
NFPA	National Fire Protection Association
WUI	Wildland–Urban Interface
WSGVAP	West San Gabriel Valley Area Plan