

# Applying Analytics to Fireground Rescue: Identifying Effective Strategies Through Large-Scale Data

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**Abstract:** This study applies advanced analytical techniques to examine firefighter rescue operations using a large-scale dataset of real-world incidents. The purpose is to identify effective strategies that enhance operational performance and improve life-saving outcomes on the fireground. Drawing on firsthand reports from firefighters involved in actual rescues, the study analyzes 5,074 documented incidents, representing over 250,000 data points collected as of January 1, 2026. The dataset captures a wide range of variables, including incident conditions, environmental factors, victim characteristics, and tactical decisions. Using quantitative methods, the analysis identifies patterns, key predictors, and relationships associated with successful rescue outcomes. Particular attention is given to decision-making under high-risk conditions, resource allocation, and timing of interventions. To ensure data quality, the Firefighter Rescue Survey (FRS) has undergone multiple iterations over a six-year period, improving reliability and relevance while incorporating practitioner feedback. Although some variables reflect smaller subsamples due to survey evolution, the dataset remains robust for large-scale analytical assessment. Findings from this study contribute to the development of evidence-based practices in fireground operations by translating complex data into actionable insights. The results have implications for firefighter training, operational planning, and policy development, ultimately supporting improved efficiency, reduced risk, and enhanced survival outcomes in emergency response environments.

**Keywords:** Firefighter Rescue Operations, Fireground Analytics, Large-Scale Incident Data, Evidence-Based Practice, Emergency Response Performance, Decision-Making Under Risk, Tactical Operations, Resource Allocation, Operational Efficiency, Risk Reduction, Data-Driven Strategies

## Introduction

Fireground operations rank among the most complex and high-risk activities in public safety, demanding rapid decision-making under conditions of uncertainty, time pressure, and incomplete information. Traditionally, knowledge guiding firefighter rescues has been derived from anecdotal experience, after-action reports, and small-scale case studies, which often lack the scope and analytical rigor necessary to systematically identify the factors that drive successful outcomes.

Recent advances in data collection and analytics now permit large-scale, evidence-based examination of operational datasets; however, rigorous quantitative analyses of real-world fireground rescues remain limited. This study addresses that gap using the Firefighter Rescue Survey (FRS), a comprehensive dataset of firsthand rescue accounts. Systematic analysis of thousands of documented rescues provides empirical insight into the influence

of decision-making, resource allocation, intervention timing, and environmental conditions on operational effectiveness.

Over six years, the FRS has been iteratively refined with practitioner feedback to ensure relevance and applicability, despite some variability across measures. By applying advanced analytical methods, this research identifies patterns and predictors of successful rescues, translating operational experience into actionable knowledge. The findings are intended to inform firefighter training, enhance on-scene decision-making, guide organizational policy, and ultimately improve operational efficiency and survival outcomes, demonstrating the essential role of analytics in modern fireground safety.

## **Literature Review**

### ***Lifestyle and Safety Practices of Firefighters and Their Relation to Cardiovascular Risk Factors***

Firefighting is a high-risk occupation, exposing personnel to injuries, illnesses, and elevated mortality rates compared to other professions. Beyond physical hazards, firefighters face thermal and emotional stress, which can increase heart rate and contribute to cardiac events, especially under heat and dehydration (Eastlake et al., 2015). They are also exposed to environmental toxins, including carbon monoxide, hydrogen cyanide, aerosols, and particulate matter, as well as high noise levels from sirens—up to 120 decibels—which can further impact cardiovascular health (Eastlake et al., 2015).

### ***Epidemiology Of Injuries To Wildland Firefighters***

In combating wildfires, firefighters face unique occupational hazards. While injuries from animal attacks, toxic plants, and extreme heat are relatively rare, slips, trips, and falls occur more frequently (Britton et al., 2013). Wildfire season coincides with the hottest, driest months, increasing the risk of heat-related illnesses such as heat exhaustion and heat stroke. These risks are inherent across all wildfire suppression scenarios, highlighting the need for prevention strategies at both social and institutional levels. Effective wildfire management requires not only local-level interventions but also protective safety protocols and preventive systems for firefighters. This systematic review examines methodologies for studying firefighter exposure to occupational hazards and their health consequences, with the goal of providing evidence-based guidance to improve safety management in wildfire suppression (Britton et al., 2013).

### ***Occupational Demands and Task Complexity***

Given the unique working environment and highly specialized occupational demands faced by firefighters, these professionals are frequently required to operate and manage heavy and cumbersome equipment while performing a wide range of complex rescue tasks. These duties often include physically demanding activities such as climbing multiple flights of stairs while carrying victims or essential gear, transporting firefighting and medical equipment, and navigating hazardous or unstable structures (Lavender et al., 2014). The combination of environmental hazards, high-intensity physical exertion, and the need for rapid, precise decision-making under time-sensitive conditions significantly increases the physical and cognitive demands placed on firefighters, making these tasks both technically challenging and physiologically taxing.

### ***Safety Risks in High-Intensity Rescue Operations***

The intricacy of these rescue tasks, combined with their high work intensity and the often unpredictable and hazardous fireground environment, has long posed significant occupational safety threats to firefighters (Zhang et al., 2024; Ras et al., 2024). The simultaneous demands of physical exertion, time-sensitive decision-making, and exposure to extreme heat, smoke, and structural instability amplify the risk of injury, fatigue, and long-term health consequences, making the management of firefighter safety a persistent and critical concern within the profession.

### ***Enhancing Rescue Capabilities and Task Efficiency***

Enhancing firefighters' rescue capabilities has been a central focus for researchers, as their proficiency in executing complex rescue tasks and their ability to effectively leverage specialized skills and training directly influence operational efficiency, response times, and overall task performance (Weidinger, 2022; Fyock-Martin et al., 2020). Improved performance not only reduces the physical and cognitive strain on firefighters but also contributes to the successful resolution of emergencies, thereby indirectly supporting national and public safety objectives by minimizing loss of life, property damage, and broader societal impacts (Heydari et al., 2022; Dowdall-Thomae et al., 2012). This dual focus on individual capability and collective safety underscores the importance of evidence-based training, performance assessment, and operational optimization in modern fire service practice.

### ***Balancing Efficiency and Risk Mitigation***

Addressing the dual challenge of enhancing the efficiency of complex rescue tasks while simultaneously mitigating the inherent safety and injury risks associated with these operations represents a critical and urgent scientific priority within the field of firefighting and emergency response (Lee et al., 2020; Chae & Seung, 2022). This issue requires not only the development of optimized operational protocols and evidence-based training programs but also the integration of ergonomic, biomechanical, and technological interventions to support firefighter performance under high-stress, high-risk conditions. Effectively balancing task efficiency with occupational safety has significant implications for reducing work-related injuries, improving firefighter resilience, and ultimately ensuring the success of life-saving interventions in diverse emergency scenarios.

### ***Empirical Questions***

The study was guided by the following research questions:

1. Which incident-level factors, such as fire conditions, structure type, and time of day, are statistically associated with successful rescue outcomes in firefighter operations?
2. To what extent does the timing of critical interventions, such as time to entry and time to victim contact, predict rescue success and survival outcomes?
3. How does resource allocation—including personnel numbers, company assignments, and equipment availability—affect operational effectiveness and rescue outcomes?
4. Which combinations of incident conditions, tactical choices, and decision-making variables most strongly predict successful rescue outcomes when examined through multivariate analytical models?

These questions highlight essential considerations in applying analytics to fireground rescue operations, emphasizing the need for further empirical investigation to elucidate how

incident conditions, decision-making processes, resource allocation, and tactical strategies affect operational performance, firefighter safety, and life-saving outcomes. Such research is critical for informing the development of evidence-based training, operational protocols, and policy within the fire service.

## **Data Analysis**

### ***Design/Sampling***

This study employs a quantitative, observational design using secondary data from the Firefighter Rescue Survey (FRS), a practitioner-driven instrument documenting real-world rescue operations. The design is retrospective and cross-sectional, analyzing previously recorded incidents to identify patterns and predictors of successful rescues. The dataset comprises 5,074 firefighter-reported rescue incidents, encompassing over 250,000 data points collected through the FRS as of January 1, 2026. These firsthand, self-reported accounts provide strong ecological validity and offer valuable insight into decision-making under authentic fireground conditions. Participation was voluntary and limited to individuals with direct rescue experience, resulting in a non-probability, purposive sampling strategy. The FRS captures a wide array of variables, including incident characteristics, environmental conditions, victim factors, and tactical decisions, supporting comprehensive multivariate analyses. Over six years, the survey has undergone iterative refinement to enhance reliability, content validity, and practical applicability, though certain variables reflect smaller subsamples due to modifications across survey iterations. Overall, the dataset's scope and granularity enable rigorous statistical evaluation of core predictors and relationships associated with effective rescue strategies, while recognizing the inherent limitations of self-reported data and non-random sampling.

## **Methodology**

### ***Results***

Analysis of residential fire rescues demonstrates that survival is strongly influenced by rescue method, timing, and environmental factors. Victims able to self-evacuate had the highest survival (98%), while common techniques such as door removal (63%) and firefighter drag (58%) yielded moderate outcomes; less common methods like webbing (49%) and victims not removed (14%) showed the lowest survival. Survival declined with delayed searches and longer total rescue times, with pre-knockdown searches achieving 69% survival versus 44% for post-knockdown, and rescues within 2 minutes reaching 76% compared to 24% for interventions exceeding one hour. Environmental conditions also played a role: closed doors (84%) and functioning smoke alarms (80%) improved survival, with both combined producing 94.7%, while elevated or accessible locations such as balconies (99%) and standing victims (100%) had the highest outcomes, and floors, kitchens, and bathrooms the lowest (50–56%). These findings underscore the critical importance of rapid, strategic intervention, effective removal methods, and fire-safe environmental design in maximizing survival.

### ***Data Collection/Presentation of Statistics***

All fireground operational data were obtained from the Firefighter mayday Survey. These data capture detailed information on incident characteristics, response actions, rescue operations, and outcomes. The use of large-scale, systematically collected data supports the application of analytics to fireground rescue, enabling the identification of effective strategies and evidence-based practices. The data indicate substantial variation in rescue frequency and associated survival outcomes based on the method of victim removal. The

most frequently employed techniques—door removal (68%) and dirty drag (65%)—were associated with moderate survival rates of 63% and 58%, respectively. In contrast, victims capable of self-evacuation (21%) exhibited the highest survival rate (98%), underscoring the critical role of mobility in enhancing outcomes. Window-based rescues indicated differential effectiveness, with feet-first extractions (87%) yielding higher survival than head-first removals (62%). Less commonly used methods, such as webbing (49%), were linked to lower survival, whereas other removal approaches achieved comparatively favorable outcomes (74–75%). Notably, victims who were not removed (1%) experienced the lowest survival rate (14%), emphasizing the essential importance of timely intervention.

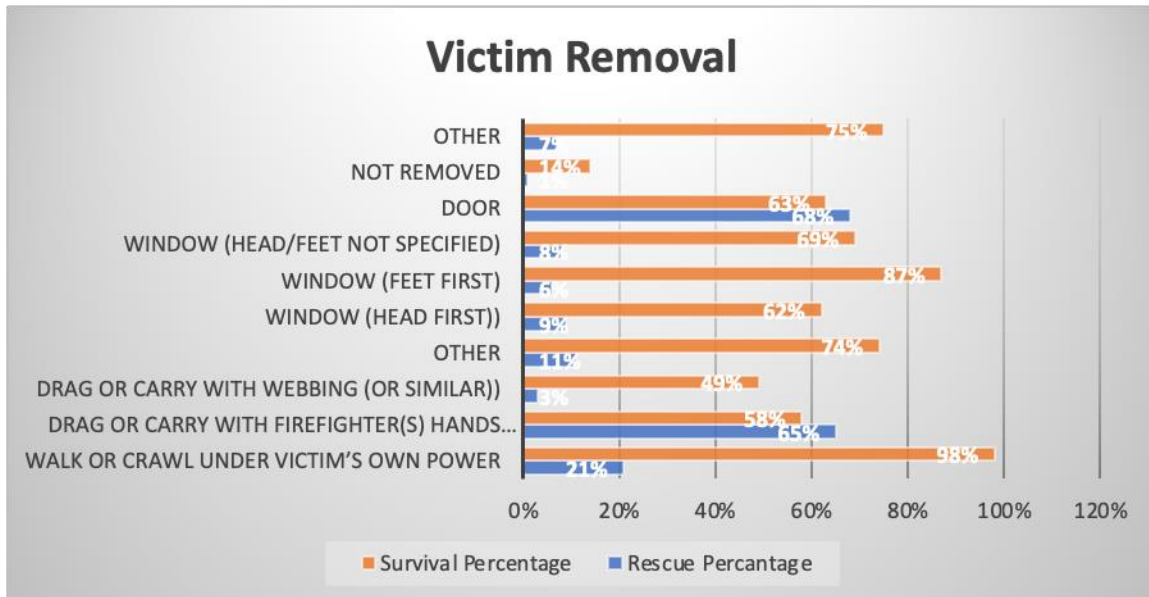


Figure 1. Victim Removal

Source: Firefighter Mayday Survey, The First 100 Report (2005)

The timing of search operations exerts a significant influence on both rescue frequency and survival outcomes. Searches conducted prior to fire knockdown accounted for the majority of rescues (62%) and were associated with the highest survival rate (69%), underscoring the critical importance of early intervention. Concurrent searches performed during knockdown comprised 30% of rescues and yielded a survival rate of 62%. In contrast, post-knockdown searches were the least common (9%) and corresponded with the lowest survival rate (44%), highlighting the markedly increased risk associated with delayed search efforts.

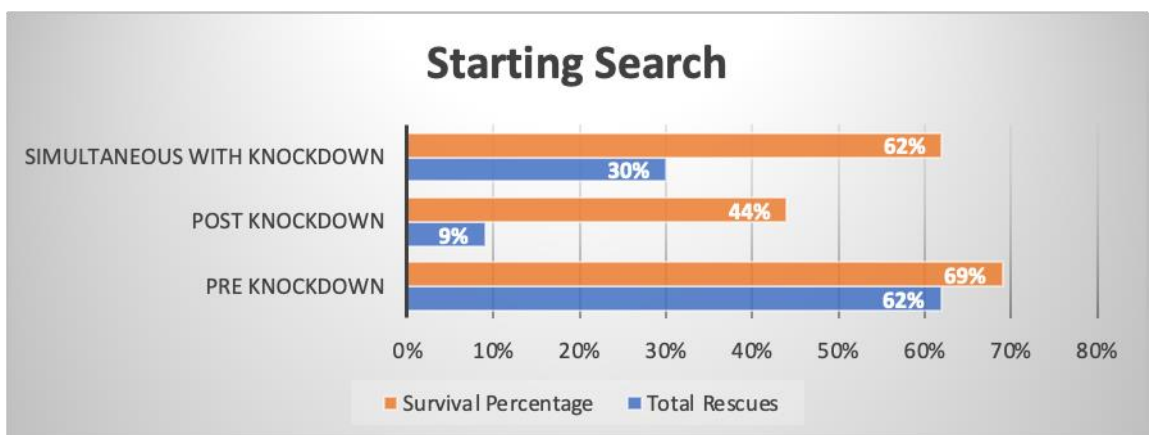


Figure 2. Starting Search

Source: Firefighter Mayday Survey, The First 100 Report (2005)

The findings indicate that both closed doors and functioning smoke alarms are associated with higher survival outcomes during residential fires. Victims located behind closed doors exhibited a higher survival rate (84%) compared to those without this protection (60%), emphasizing the protective effect of compartmentalization. Similarly, the presence of operational smoke alarms increased survival (80%) relative to non-functioning (61%) or unknown alarm status (58%). The greatest benefit was observed when both measures were present: survival reached 94.72% for victims behind a closed door with a working smoke alarm, demonstrating a strong synergistic effect. Closed doors alone conferred notable protection (78.21%), whereas survival declined when doors were open, even with alarms (72.35%), and was lowest when neither safeguard was present (56.55%).

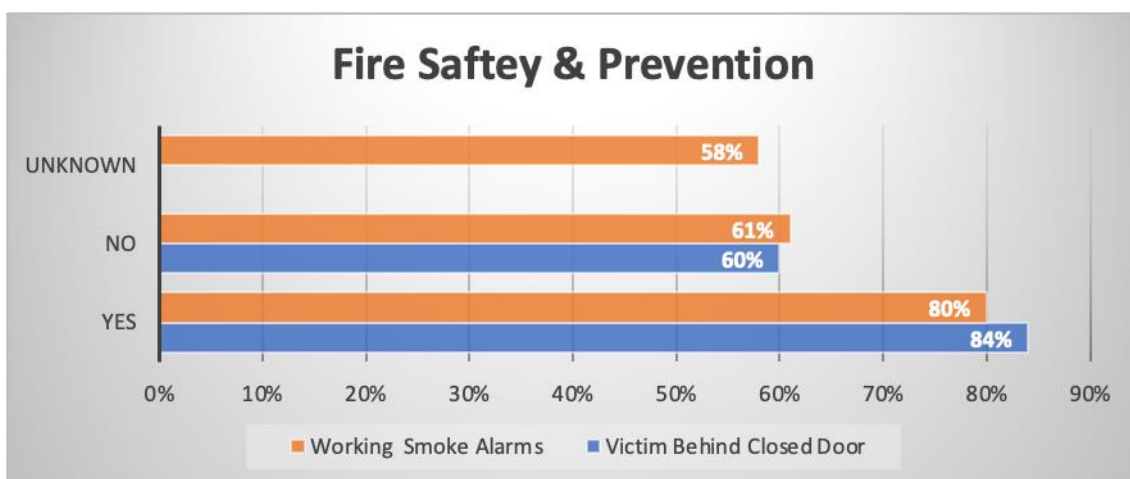


Figure 3. Prevention

Source: Firefighter Mayday Survey, *The First 100 Report* (2005)

This analysis examines residential rescue locations and associated survival rates to inform fire safety strategies. Survival was highest among individuals who were standing (100%, 14%), on balconies or decks (99%, 5%), in cribs (77%, 1%), on stairs (74%, 2%), or in other locations (80%, 12%), indicating that proximity to exits or elevated spaces enhances survivability. Moderate survival occurred in bedrooms (64%, 45%), on beds (67%, 15%), couches (64%, 6%), closets (65%, 1%), top bunks (67%, 1%), foyers (64%, 2%), and other rooms (72%, 6%). Lowest survival was observed on floors (54%, 36%), in kitchens (53%, 7%), bathrooms (56%, 6%), laundry rooms (50%, 1%), under beds (49%, 1%), near exterior doors (51%, 10%), and in vehicles (0%, 1%). These findings underscore the critical importance of functional smoke alarms, accessible egress routes, and proactive planning, particularly for high-risk areas and vulnerable populations.

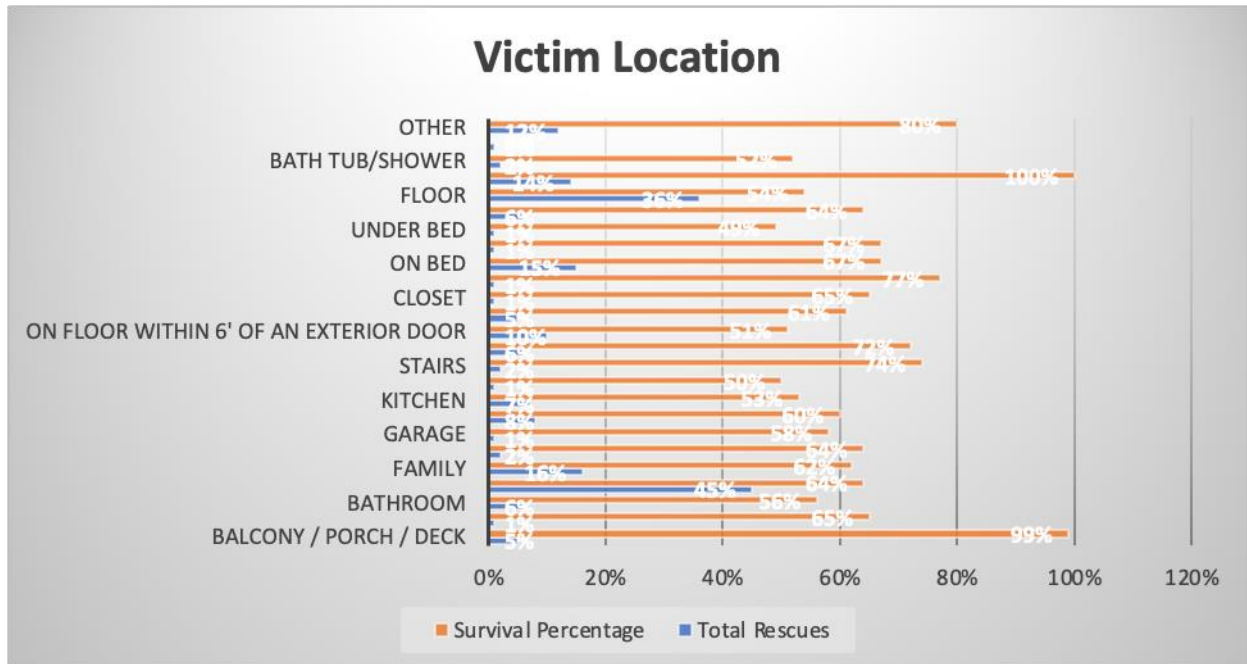


Figure 4. Victim Location

Source: Firefighter Mayday Survey, The First 100 Report (2005)

Analysis of residential fire rescues indicates a pronounced inverse relationship between total rescue time—from fire department arrival to victim extrication—and survival probability. The majority of rescues were completed within the first six minutes, with 2–4 minutes representing 20%, 4–6 minutes 16%, and under 2 minutes 15% of all rescues. Survival was highest among victims removed within 2 minutes (76%) and remained comparably favorable for 2–4 minutes (75%), but declined progressively with longer rescue intervals: 4–6 minutes (68%), 6–8 minutes (65%), 8–10 minutes (66%), 10–15 minutes (63%), 15–20 minutes (49%), and 20–30 minutes (46%). Rescues occurring between 30 and 60 minutes yielded 55% survival, whereas interventions exceeding one hour were associated with the lowest observed survival (24%). These findings provide compelling evidence that minimizing total rescue time is a critical determinant of survival, with each incremental delay significantly diminishing the likelihood of a favorable outcome.

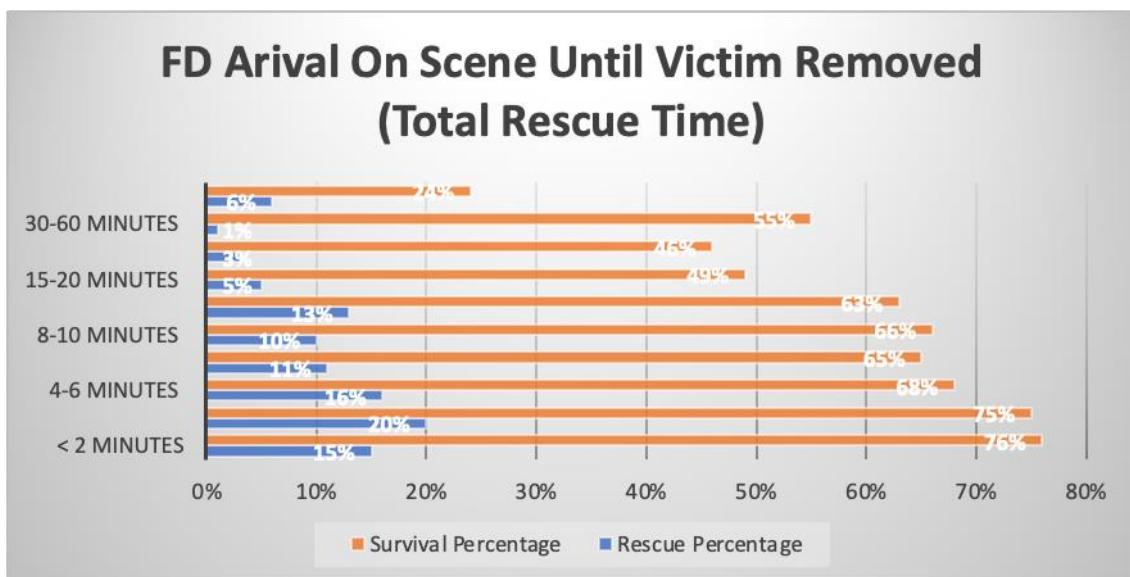


Figure 5. Total Rescue Time

Source: Firefighter Mayday Survey, The First 100 Report (2005)

## **Limitations**

While this study utilizes a large-scale, real-world dataset to identify effective fireground rescue strategies, several limitations warrant consideration. The reliance on self-reported data introduces potential recall bias and social desirability effects. Additionally, some variables are derived from smaller subsamples due to the iterative development of the Firefighter Rescue Survey, which may constrain certain subgroup analyses. The use of non-random sampling further limits the external generalizability of the findings. These limitations are explicitly considered in the interpretation of results and should be taken into account when applying the insights to broader operational contexts.

## **Implications of Findings**

The results of this study carry important implications for fireground operations and emergency management. By elucidating patterns and key predictors of successful rescues, the findings offer evidence-based guidance for firefighter training, highlighting the importance of rapid intervention, effective search and removal techniques, and decision-making under high-risk conditions. Operational effectiveness can be enhanced through data-driven resource allocation, tactical prioritization, and the establishment of protocols designed to minimize rescue time and optimize survivability. Additionally, the insights inform policy development aimed at strengthening fireground safety, including the promotion of functional smoke alarms, compartmentalization practices, and accessible egress within residential environments. Overall, this research demonstrates that large-scale, quantitative analysis can transform operational experience into actionable strategies that improve efficiency, mitigate risk, and maximize life-saving outcomes.

## **Discussion/Recommendations**

The findings from this large-scale analysis of firefighter rescue operations identify several critical factors that shape survival outcomes and operational effectiveness. Rescue method, timing, environmental conditions, and accessibility consistently influenced survivability, highlighting the complex interplay between tactical decisions and situational variables on the fireground. Rapid intervention, effective search and removal techniques, compartmentalization, functional smoke alarms, and accessible egress emerged as key determinants of successful outcomes. Elevated survival rates among self-evacuating victims and those in accessible or elevated locations underscore the importance of mobility and early evacuation in life-saving scenarios.

These insights carry important implications for fire service practice. Training programs should incorporate evidence-based strategies that emphasize rapid search and rescue, prioritization of high-risk areas, and the use of removal techniques tailored to environmental conditions. Operational planning should ensure resource allocation and incident command protocols support minimized rescue times and timely intervention. Additionally, public safety initiatives should continue to promote functional smoke alarms, closed-door compartmentalization, and awareness of escape routes to enhance civilian survivability.

Future research should extend this work by integrating real-time sensor data and post-incident evaluations to refine predictive models of rescue success. Collectively, these findings demonstrate that systematic, data-driven approaches can transform operational experience into actionable guidance, improving firefighter performance, mitigating risk, and enhancing survival outcomes in residential fire emergencies.

## Conclusion and Future Scope

This study illustrates that large-scale, data-driven analysis of firefighter rescue operations can generate actionable insights to enhance operational effectiveness and improve survival outcomes. By examining 5,074 documented incidents encompassing over 250,000 data points, the research identifies key predictors of successful rescues, including rapid intervention, effective removal techniques, strategic decision-making, and environmental factors such as compartmentalization and accessibility. These findings underscore the critical role of evidence-based approaches in guiding firefighter training, resource allocation, and operational planning to reduce risk and maximize life-saving outcomes on the fireground. Future research should build upon these results by integrating real-time and sensor-based data, investigating the influence of team dynamics and communication on rescue performance, and validating predictive models across diverse operational contexts. Continued enhancement of large-scale datasets and analytical frameworks will support the development of evidence-based strategies, strengthen firefighter preparedness, and advance civilian safety in residential fire emergencies.

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