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Considering human factors during firefighter fatality investigations: Insights from public feedback

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ABSTRACT

Introduction: The National Institute for Occupational Safety and Health (NIOSH) Fire Fighter Fatality Investigation and Prevention Program investigates firefighter line-of-duty-deaths (LODD) and serious injuries to help prevent incidents. In addition to physical hazards, human factors like situational awareness, mental workload, fatigue, culture, and decision making can be considered to identify and mitigate risks. *Method:* NIOSH sought public input on assessing human factors during investigations through a Federal Register Notice. Posted in May 2024, 33 responses were received from fire departments, academic institutions, and association representatives across 18 U.S. states and several Canadian provinces. Three researchers and two firefighters examined the comments using thematic qualitative analysis methods to identify human factors considerations during investigations. *Results:* Comments indicated general support for systematically assessing human factors elements and provided insight into what some of those elements may be. Five overarching themes emerged across the comments: *Department Culture, Total Worker Health®, Operational Risk Management & Decision Making, Team Dynamics,* and *Training and Education.* Within these themes, commenters highlighted the importance of considering individual human factors elements such as fatigue, situational awareness, and mental health as well as organizational human factors elements such as leadership commitment and communication, operational risk assessment, and training needs. *Conclusions and Practical Applications:* Future research may consider ways to empirically and routinely assess human factors during incident investigations and possible tools, frameworks, and training that may be necessary to support these efforts in the field.

1. Introduction

U.S. firefighters, who encounter a range of hazards on and off the fireground that can result in injuries, illness, and death (Fahy, Evarts, & Stein, 2022), experience mortality at a higher rate than those in other job roles (DeJoy et al., 2017). In some scenarios, firefighters encounter and experience risks similar to those in other occupations, such as slips, trips, and falls (Britton et al., 2013). However, other risks, such as the quick onset of heat exhaustion and the challenges of working in dynamic, quickly changing environments, are more unique to the fire service and can trigger emotional and thermal stress and negative cardiac outcomes (Britton et al., 2013). Leading causes of line-of-duty deaths (LODDs) have remained relatively stable over the last decade (Campbell & Petrillo, 2024). In 2023, 89 firefighters died from traumatic injuries, heart attacks, strokes, or aneurysms within 24 h of duty, with 73 of those deaths occurring while on-duty (Campbell & Petrillo, 2024). In 2022, firefighters experienced 65,650 injuries in the line of duty, an 8% increase from 2021 (Campbell, 2024).

Several efforts exist to reduce firefighter risks, especially those associated with interior firefighting. Examples include incident command responsibilities, requirements for size-up and risk assessment, promotion of communication systems and personal alert safety system (PASS) devices, specifications for personal protective equipment (PPE), training in fire dynamics, and other safety-related practices and interventions (Jardin & Madrzykowski, 2021). Similar considerations have been highlighted in the National Institute for Occupational Safety and Health (NIOSH) Fire Fighter Fatality Investigation and Prevention Program (FFFIPP) LODD reports to help prevent future incidents (e.g., see NIOSH, 2025a).

Investigations and reports outline technical gaps that might be

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contributing factors to a fatality; however, human factors deficiencies have been shown to exacerbate exposures and hazards (Moore-Merrell et al., 2006). Investigators have not consistently assessed human factors elements during investigations, although there have been requests from fire service partners to consider this information (Clark, 2024; Leadership Under Fire [LUF], 2022; NIOSH, 2022). NIOSH recognized this feedback as an opportunity to more formally explore what human factors elements could be considered and how to best integrate them into LODD and serious incident investigations. Consequently, NIOSH posted a Federal Register Notice Request for Information (RFI) to gain public feedback on this topic (Vol. 88, No. 99). Thirty-three substantial comments were received.

The purpose of this paper is to systematically discuss the public comments and how it might inform future investigations. After providing an overview of the FFFIPP, we briefly define human factors elements as they may relate to incident investigations. Then we describe our thematic analysis process, which revealed human factors elements emphasized throughout the comments. Feedback received and consequently discussed in this paper focus on five overarching themes that encompassed aspects of Total Worker Health®, department culture, organizational and operational risk management, communication practices and team dynamics; and mechanisms to improve firefighter training and education.

2. Firefighter line-of-duty-death investigations

Since its inception in 1998, the NIOSH FFFIPP has conducted independent LODD traumatic and medical investigations to identify contributing factors and provide actions to help prevent similar deaths and serious injuries. To date, the program has completed over 750 investigations across the United States and those final reports are available on the NIOSH FFFIPP website (NIOSH, 2025a). Examples of common contributing factors and correlating prevention actions for trauma-related LODDs are shown in Table 1.

2.1. Human factors in current investigations

Human factors refer to a range of elements from cognitive, physical, social, and organizational, that may influence individual decisions and performance when carrying out job-related operations (Bridger, 2021). Human factors elements may impact how the body (i.e., both physical and physiological factors such as fatigue, nutrition, and hydration) and mind (i.e., psychological factors such as situation awareness, self-confidence, and trust in team members) operate (Clark, 2024; Omodei et al., 2005). The aviation industry is particularly known for work in this area, as research has found that human factors are a primary or secondary cause of 70–80 % of aviation mishaps (Federal Aviation Administration, 2023). A common framework used in aviation is the Human Factors Analysis and Classification System (HFACS [HFACS Inc., 2014]), which has been modified and applied in other industries. The basis of the HFACS is Reason's Swiss cheese model (Reason, 2008), which describes four corresponding levels of failure for each of Reason's layers: unsafe acts; preconditions for unsafe acts; unsafe supervision; and organizational influences (Wiegmann & Shappell, 2009). Within these four HFACS levels, several sub-components exist (e.g., resource management under organizational influences, adverse mental state under precondition for unsafe acts) operating within the premise that routine, skill-based behaviors are vulnerable during adverse scenarios (Wiegmann & Shappell, 2009). Although firefighters train for adverse scenarios, it does not mean that their physiological state or physical and mental limitations do not come into play when responding to a fire.

Consequently, human factors, especially as outlined in the HFACS, are thought to contribute to a large proportion of adverse incidents during fireground operations, training, and response (Butler et al., 2023; Guidotti, 1992; Moore-Merrell et al., 2006). For example, one analysis revealed that human factors elements were a primary contributor to 80% of incidents among wildland firefighters (e.g., risk propensity, organizational factors, and safety culture; Madrzykowski, 2024). Another analysis of 189 FFIPP reports from 2004 to 2009 suggested that the higher risk tolerance embedded in firefighting culture was one root cause of adverse incidents (Kunadharaju, Smith, & DeJoy, 2011). To this end, considering human factors elements may support more predictable decision making and focused interventions by understanding how these elements may impact firefighters' psychological and physiological responses during critical scenarios (Johansson, Hollnagel, & Granlund, 2002). Additionally, considering these elements may aid in identifying immediate causes as well as underlying organizational, cognitive, and behavioral issues that may contribute to adverse incidents (Dekker & Conklin, 2014; Hollnagel, 2014).

An external review of FFFIPP reports revealed some trends in considering human factors elements albeit informally (i.e., communication and situational awareness) (LUF, 2022). When encouraged to consider human factors during investigations, a challenge has been how to do so in a way that does not assign blame (NIOSH, 2022; Clark, 2024). However, given the consistent occurrence of injuries and fatalities among firefighters, it is possible that the fire service and individual firefighters could benefit if investigations sought to more consciously consider and incorporate human factors elements, when applicable. Long-standing community partners such as the National Volunteer Fire Council (NVFC) and the International Association of Fire Fighters (IAFF) have also advocated for better acknowledgement of human factors in FFFIPP investigations (NIOSH, 2022). Based on this ongoing feedback, NIOSH sought to more explicitly and systematically identify opportunities to explore elements that may impact firefighter injury and death.

Table 1
Examples of Contributing Factors and Correlating Prevention Actions Identified during NIOSH FFFIPP Trauma Investigations.

Example Contributing Factor	Example Correlating Prevention Action
Size-up and risk assessment	Initial and ongoing size-ups and risk assessments are conducted throughout the incident.
Crew integrity	Company officers and firefighters maintain crew integrity (i.e., stay together and function as a team, ensuring no one gets separated) when operating in the hazard zone.
Personnel accountability	Incident Commanders establish divisions/groups with a supervisor to communicate conditions and provide accountability.
Rapid intervention team/ crew	A rapid intervention team/crew is dedicated, assigned, and in place before interior operations begin and throughout an incident.
Simultaneous interior and exterior operations	Interior and exterior operations, such as water applications, do not conflict.

3. Materials and Methods

NIOSH used the *Federal Register* to solicit a voluntary Request for Information (RFI) from the public about the potential inclusion of human factors elements during traumatic LODD and serious injury investigations. The *Federal Register* is published daily by the federal government and contains information about proposed rules and notices of interest to the public that can be responded to in the established docket. The RFI, titled "Human Factors Considerations for the Fire Fighter Fatality Investigation and Prevention Program" – Vol. 88, No. 99, was open May 21–July 22, 2024 (Federal Register, 2024). The RFI probed general interest in human factors and elements to consider; methods that could be used to collect and incorporate human factors elements into investigations; and how to incorporate human factors findings and recommendations into reports without placing blame on fire departments or firefighters.

Specifically, the RFI provided examples of human factors elements in the fire services that were anecdotally or indirectly provided to NIOSH

as being important (e.g., NIOSH, 2022; Clark, 2024) such as decision-making under operational stress, communication practices including team dynamics and leadership, safety culture, and physiological stress and resilience (Federal Register, 2024). These elements, along with the HFACS, discussed earlier as a relevant framework for fireground operations, provided a priori umbrella for our overarching themes. Within this umbrella, however, we anticipated that new codes and more nuanced subcodes would emerge inductively from the public comments. Consequently, this paper reports on the analysis of the aggregated public comments to specifically answer: "What specific human factors elements should be considered during traumatic LODD and serious injury investigations?" This activity was reviewed by CDC, deemed not research, and was conducted consistent with applicable federal law and CDC policy.[1]

3.1. Commenter sample

Thirty-nine public comments were entered into the docket over the 60-day period. Of these, six were non-substantial (not about this topic) or duplicates (someone submitted the same comment twice). Of the 33 remaining comments, 14 (43%) were from individuals still employed at fire departments across North America; five (15%) represented universities; five (15%) fire service representative associations; seven (21%) private companies; and two (6%) from other government agencies. Comments were submitted across 18 states in the United States, the District of Columbia, and from several Canadian provinces. See Fig. 1 for a breakdown of the commenters and Fig. 2 for the geographic representation of the comments.

3.2. Thematic qualitative analysis

Thematic qualitative analysis (TQA) is used to objectively analyze and describe patterns within narrative data, including differences across groups (Braun & Clarke, 2006, 2022a, 2022b; Elo & Kyngäs, 2008). TQA is useful when documents address a similar topic but there is a need to condense information into fewer categories to characterize prominent patterns (Braun & Clarke, 2006). These attributes made this method particularly helpful to explore human factors elements. Researchers adapted Braun and Clarke's six-step thematic analysis framework (Braun & Clarke, 2006) to guide a reflexive coding process (Braun & Clarke, 2022a, 2022b).

We adopted a hybrid deductive-inductive approach during data analysis. The initiation of codes was deductive in nature as most feedback from the fire service community was provided using the umbrella probes presented in the RFI (Federal Register, 2024) and the HFACS framework such as communication and team dynamics, safety culture, fit-for-duty considerations, operational stress, leadership, and organizational influences. This deductive structure ensured alignment with the RFI's intent and body of knowledge previously reviewed. However, the initial coding process, described below, was approached from an inductive lens during line-by-line reviews, allowing specific human factors elements presented by commenters to further shape codes and subcodes. This hybrid approach was important to capture both the context-specific concerns that have been captured in literature while being open to novel or emerging elements that were specific to the fire service community.

3.2.1. Preparing responses and initial coding

The 33 comments ranged from 1 to 16 single-spaced pages with the average response running three pages. During initial coding, one researcher and two firefighters read each response line by line to identify human factors elements that the public advised us to consider, including potential advantages and concerns surrounding each of the elements. We identified several individual- and organizational-level human factors elements that were consistent with the RFI and previous feedback received in a broad sense (i.e., organizational leadership, safety culture, crew communication). We drafted a codebook template that contained these umbrella themes but also potential, more nuanced codes and subcodes to guide and provide transparency to subsequent coding steps. The inclusion of two firefighters in the development of the draft codebook was critical to ensure the nomenclature was accurate for further analysis and categorization.

3.2.2. Focused coding and code reviews

Next, three researchers met and collectively coded the comments to the draft codebook. We copied all comments into a word document where, next to each comment, a human factors element was coded to an overarching theme (e.g., *Department Culture*) and if applicable, a lower-level code (e.g., Psychological Safety as a part of *Department Culture*). While the overarching themes reflected a broad framework derived from the RFI probes and previous literature, the codes often emerged inductively from the comments, capturing issues that were either more specific to the fire services or more nuanced with the potential to transcend across themes.

After we coded all comments using the codebook, the lead author met with the two firefighters again to complete subject matter expert reviews of the assigned codes. During this meeting, the firefighters provided contextual feedback that helped operationalize definitions and finalize placements of certain codes and subcodes within themes. This subject matter expertise was critical for refining the inductive codes within the deductive themes and homing in on the operational language and contexts relevant within the fire service. For example, they identified ways that management communication specific to team dynamics was functionally different than management communication that may support and influence the department culture.

3.2.3. Code revisions and final codebook

After reviewing the coded content, we counted the occurrence of each code. Although TQA does not usually provide enumerated reporting, we wanted to identify areas of perceived importance and priority, as provided by the commenters (Corbin & Strauss, 2008; Saldaña, 2016). During our final inductive review and refinement of the codebook, we noticed and resolved unnecessary redundancies and made approximately five updates. For example, originally Safety Management Systems was its own theme in the codebook. However, with only a few references across all 33 comments, we moved this theme as a code under *Operational Risk Management & Decision Making*. Also, we originally had Community Relations as a separate theme that, upon further analysis, only had a few references and was integrated into the External Relations code under *Department Culture* to encompass all external communications. Finally, we initially had various Fit for Duty subcodes (e.g., nutrition, cardiovascular health, hydration). Separately, these codes had one to two specific references and were combined into a holistic Fit for Duty code.

After completing initial, focused, and iterative coding, we met to discuss and ensure general agreement on the coded results and definitions. These revisions supported the initial umbrella themes, anchored in a priori categories from the Federal Register RFI, while codes and subcodes were inductively refined to reflect the perceptions of commenters. Operational definitions were revisited and finalized using the context provided within the comments themselves to best describe and encompass the narrative feedback. It was important to conduct a final review of the codes to not only ensure saturation (Corbin & Strauss, 2008), but also to highlight areas that may warrant integration into future investigations.

1 § See e.g., 45C.F.R. part 46, 21C.F.R. part 56; 42 U.S.C. §241(d); 5 U.S.C. §552a; 44 U.S.C. §3501 et seq.

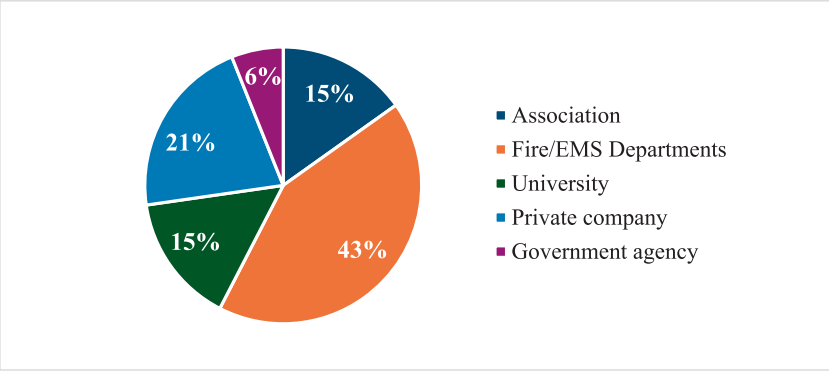

Fig. 1. Affiliations of commenters.

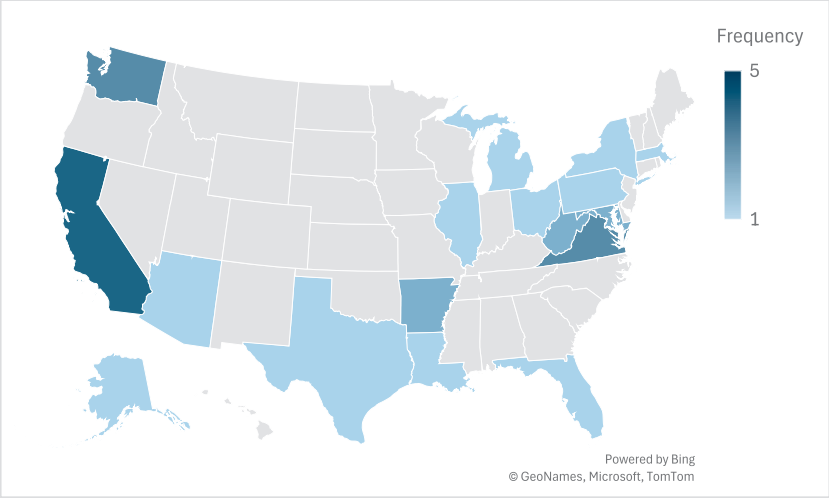

Fig. 2. U.S. Geographic Breakdown Showing Frequency of Comments by State (Canadian provinces (n = 5) not shown).

4. Results

The public comments allowed us to identify human factors elements perceived to be the most important among fire service partners specific to traumatic LODD and serious injury investigations. Five themes emerged (Table 2). *Department Culture* received the most comments (n = 60), followed by *Total Worker Health®* (n = 54), *Operational Risk Management & Decision Making* (n = 26); *Team Dynamics* (n = 23); and *Training and Education* (n = 17). This categorization of themes reflects the analytic framework described in the Methods section, where the RFI probes guided overarching themes, and specific codes were inductively refined within those themes.

The specific codes that fell within each of these themes, including their operational definitions, are reported in the subsequent sections.

Table 2
Five Overarching Themes across Human Factors Public Comments.

Human Factors Theme	References (#)	Operational Definition
Department Culture	60	Shared norms and values that shape behavior, risk tolerance, and learning. The consistency, visibility, and quality of leadership in modeling and reinforcing safe practices also influences these norms and values.
Total Worker Health®	54	Integrated approaches that prioritize firefighter well-being by accounting for personal health, recovery, and workload realities.
Operational Risk Management & Decision Making	26	Systems and tools that support high-quality decisions and risk mitigation before, during, and after incidents.
Team Dynamics	23	Interpersonal functioning of the crew, including communication, morale, and experiential trust that supports or hinders safe operations.
Training and Education	17	Formal and informal processes that build job competence, mental models, and response readiness.

4.1. Department culture

We deduced comments to define *Department Culture* as shared norms and values that help shape behavior, risk tolerance, and learning within a department. Terms such as organizational culture, organizational climate, safety culture, and risk culture were used throughout the comments; however, several commenters explicitly noted the need to consider department culture as an overarching aspect of all other subcultures that influence behavior across a department. With concurrence from our two firefighter SMEs, we called out department culture separately, to which we identified five codes (Table 3).

Preconditions for behaviors received the largest proportion of comments, capturing a department's safety culture. Simply put, Commenter 2 stated investigations "Should consider safety climate after a death, which has been shown to be predictive." Commenter 5 also noted:

> Environmental and physical factors alone might be the contributing factors in a death, but if a safety-averse culture is identified in the

Table 3
Department Culture Codes across Public Comments.

***Department Culture* Codes**	**References (#)**	**Operational Definition**
Preconditions for Behaviors	18	Norms, habits, systemic pressures, and penalties influencing everyday decisions and violations.
Psychological Safety	15	Individuals feel safe speaking up, admitting mistakes, or sharing concerns. Management may have an influence on personnel openness, vulnerability, and perceived protection from retaliation.
Management Support, Communication, and Accountability of SOGs/SOPs	15	Management communicates, enforces, models, and updates procedures to ensure standards and policies are followed and maintained.
External Relations	6	External department interactions (e.g., union, public) that shape risk perception, hazard identification, and safety improvements.
Workforce Engagement and Development	6	Degree to which employees are involved in safety decisions, improvement initiatives, and ongoing learning/skill enhancement.

department, this information is useful context to help departments reviewing the LODD to improve their policies, procedures, and practices.

This code also included comments about routine and exceptional safety deviations across a department and whether these actions are managed over time. On this point, some comments noted the value in exploring how departments understand, calculate, and communicate risks to personnel and under what circumstances risks might be tolerated (e.g., the threat to firefighter safety is low).

Psychological safety was also mentioned as an indicator of department culture. For example, Commenter 6 explained it might be useful for FFFIPP investigations to, "Find a way to assess the psychological safety, or lack thereof, within the department and ascertain whether it influenced the decision-making processes that may have contributed to a LODD." More broadly, comments emphasized the value in knowing if members were punished for honest mistakes, if there was a culture of fear, or desire for disciplinary action. Both culture and psychological safety can be subjectively measured via various assessments, several of which commenters referenced in their responses.

Responses also noted the importance of following standard operating guidelines or procedures (SOGs/SOPs). In this code, supervisor modeling of department-specific protocols was discussed with a focus on the presence and subsequent support of well-developed risk assessment plans and mitigation strategies in SOGs/SOPs. Commenter 8 explained the perceived importance of having strong SOGs/SOPs and making sure they are understood among responders, indicating that good protocols might reduce cognitive load. Alternatively, several responses noted the perceived negative role that poor SOGs/SOPs can have during operations. Regarding supervisor verbal support and modeling, commentors asked questions like, "Are managers held accountable for lack of performance or disregard of policy?" (Commenter 10) while other comments emphasized the need to track ongoing supervisory violations around SOGs/SOPs, if applicable.

External Relations referenced engagement with the public, labor unions, and community partners. Commenters noted that public trust, image, and other external factors can come together to influence department and firefighter decisions. Examples of questions asked around this topic included: (1) Were there opportunities to reduce the severity of the incident via community outreach or education? (2) Was the address or building a known problem, and had it been communicated up the chain of command? and (3) Did we fail to communicate with the public on the importance of smoke detectors, closing doors, and the life safety hazards associated with heavy content?

For Workforce Engagement and Development, there was an emphasis on whether departments were committed to ongoing learning and skill enhancement and the degree to which employees were involved with improvement efforts that affected them on the job (e.g., changes in tactics and PPE). Responses noted the potential value in identifying the department culture around learning and training, and whether there was an emphasis on seniority or performance.

4.2. *Total Worker Health*®

Total Worker Health® (TWH) was not specifically stated in the responses by this term. But comments consistently aligned with the definition of TWH – i.e., "policies, programs, and practices that integrate protection from work-related safety and health hazards with the promotion of injury and illness-prevention efforts to advance worker well-being" (NIOSH, 2025b, np), denoting this theme assignment with four codes (Table 4). The codes that emerged within this theme were consistent with the HFACS level preconditions for unsafe acts and sublevels around condition of operators and personnel factors. Specifically, we captured several personnel readiness factors such as fatigue, fitness for duty, and resilience, outlined below.

Fatigue was overwhelmingly mentioned specific to shift schedules, on-duty hours, secondary employment, and sleep quantity and quality in the 24–72 h preceding an incident. Shift schedule was especially emphasized. For example, Commenter 8, a West Coast fire department, noted the need to investigate, "Is 48 on, 96 off the best scenario? Second day you operate in a sleep deprived state." Similarly, Commenter 10 explained that not only can hours of sleep within the last 48 h be considered, but also the tasks assigned prior to a fatal incident including training events. Finally, accounting for fatigue from off-duty time was discussed, especially in reference to off-duty employment for volunteer firefighters and family time.

Fit for Duty, a term that can be used to reference several aspects of health and wellness, was referenced often but unsurprisingly, the specific focus varied across responses. For example, comments around the impact of proper hydration and nutrition were discussed as well as cardiovascular or overall physical fitness. Physical fitness levels were discussed as an aspect that could enable and hinder safe task execution. Together, these comments informed a holistic view of indicators that might influence firefighter fitness and ability to perform essential tasks and meet job demands.

Next, several response comments informed a Resilience code that focused on the value of knowing firefighters' previous exposure to traumatic incidents and possible post-traumatic stress that may influence response capabilities. For example, Commenter 9, made on behalf of a fire service association, stated, "We need to know acute stress at the

Table 4
Total Worker Health Codes across Public Comments.

***TWH* Code**	**References (#)**	**Operational Definition**
Fatigue	23	How work patterns and sleep characteristics contribute to an individual's state of fatigue and their ability to perform effectively.
Fit for Duty	12	A comprehensive assessment of a firefighter's readiness to perform duties effectively and safely.
Resilience	14	Psychological recovery from stress and trauma; includes chronic exposure impacts and mental wellness.
Organization Support	5	Systems and processes that promote employee well-being and safety.

time of dispatch and if this affects risk perception and risk-taking behavior." Commenters also acknowledged the potential cumulative impact of exposure over time.

Finally, the role of organizational support to facilitate TWH in the fire services was highlighted, often in the form of comprehensive benefits. Examples were accessible sick leave and wellness programs; procedures for assessing fitness for duty – particularly after medical leave or injury to facilitate safe transitions back to work; and hiring standards that prioritize and align with worker well-being. Many responses focused on accountability at the organizational level, with Commenter 27 noting the need for departments to conduct regular mental fitness checkups to quantify issues. This information was also noted as being able to aid investigators in ascertaining potential trends in worker well-being.

4.3. Operational risk management & decision making

We identified four codes (Table 5) in the *Operational Risk Management & Decision-Making* theme that focused on the systems and tools available to support high-quality decisions and risk mitigation before, during, and after events. The codes that emerged within this theme were consistent with the HFACS level "unsafe acts," which links resource management as well as decision, skill-based, and perceptual errors with accuracy and readiness rather than organizational culture (HFACS Inc., 2014).

Developing firefighters' mental models, or situational awareness, was discussed as the ability to make appropriate decisions based on the threats present during a response. Although mental models can also be an outcome of training, comments that contributed to this code were specific to cognitive framing as a precondition for safe or unsafe actions. Commenters expressed the desire for investigators to obtain more clues about what went into firefighter decision making including their current or last known mindset, mental models, and adaptivity. Commenter 15 provided several examples:

> *Incident-specific details, information about new crew members, organizational factors including defenses, barriers, and safeguards the organization had for accident prevention; and latent failures (systemic human influences) and active failures (individual human variables) while considering local working conditions.*

These data points were desired to help understand possible miscommunications and the root cause for common misunderstandings (e.g., portable radio bandwidth).

Although resources have been denoted as a symptom of culture, the HFACS classifies resource management and organizational climate as separate components under organizational influences (HFACS Inc., 2014). This aligns with the comments in the current study, which positions resource allocation as something that more often impacted decision making. Specifically, resource allocation focused on two key areas: first, whether sufficient personnel were available to fight the fire and second, whether tools, workspaces, and PPE were accessible. These were tagged as need-to-know items during an investigation. Concerns were also raised that insufficient resources such as budget could affect firefighter readiness by limiting training opportunities and compromising effective decision-making.

Fewer responses focused on assignments during prearrival and incident response as well as the presence of a safety management system (SMS). Relatedly, comments questioned whether the dispatch information provided may have influenced responders' perception of risk and subsequent decision-making. For example, Commenter 8 stated, "Any LODD report should investigate which command model the department was using (i.e., centralized vs. decentralized) and if it negatively affected human factors in decision making." Specific to SMS, some comments indicated that it could be helpful to know and examine the department's management system to identify and mitigate hazards before an incident occurs and during operational activities.

Table 5
Operational Risk Management & Decision-Making Codes across Public Comments.

***Operational Risk Management & Decision-Making* Code**	**References (#)**	**Operational Definition**
Mental Model Development	12	Understanding environments and predicting threats; shaping decisions via cognitive framing.
Resource Allocation	7	Availability and distribution of personnel, equipment (e.g., PPE, communication mediums), and budget for safety.
Prearrival and ongoing assignment	4	Clarity of roles, staging, and leadership structure before engagement and during emergency scenarios.
Presence of a Safety Management System	3	Formal system guiding safety processes, audits, improvements, and near miss systems.

4.4. Team dynamics

Interpersonal contexts were heavily emphasized in the public comments. The *Team Dynamics* theme encompassed three codes (Table 6). Responses focused on the value of a strong and transparent crew that fostered communication, morale, and experiential trust. Collectively, these dynamics could either support or hinder safe rescue operations, hence commenters' interest in these dynamics being assessed by investigators. Experience of crews was emphasized regarding how long the crew worked and trained together and the general effectiveness of the responding crew. Some responses noted the value in knowing the response experience of each crew member and any changes to crew personnel in the last few months.

As Table 6 shows, morale emerged as a recurring theme, with responses linking low morale to poor organizational culture or team dynamics, suggesting it could impact crew effectiveness. For example, Commenter 27 stated:

> *If people lack camaraderie and psychological safety, they will have a reduction in resilience and ability to ask for help when needed for fear of retribution, hostility or loss of job…environment of intimidation, isolation, self-doubt, harassment, and hazing leads to lack of community.*

This commenter went on to note that these tenets can lead to ineffective teams that make more mistakes, errors, and poor response decisions.

There was also an expressed interest in how team dynamics may affect peer and management communication during an incident. Several responses focused on the management structure of a crew and how the structure impacts communication and response. For example, one comment referenced the need to know if a crew collectively adopted practices in line with crew resource management. Specifically, if an

Table 6
Team Dynamics Codes across Public Comments.

***Team Dynamics* Code**	**References (#)**	**Operational Definition**
Experience of crew	9	Familiarity, collaboration history, and shared knowledge among team members.
Morale	7	Emotional safety and group cohesion influence sense of belonging and accountability.
Peer & Management Communication	7	Clarity, trust, and openness within the team, including upward and peer communication, to address interpersonal risk and breakdowns.

officer or incident commander is not perceived as the one in charge, it might stifle communication and reduce concerns reported by other crew members. A few responses connected this trend in the feedback to assigning blame when leadership was not properly exercised during a response.

4.6. Training and Education

The *Training and Education* theme noted formal and informal processes that were relevant to building firefighter and crew job competence, mental models, and response readiness. We categorized training and education separate from other, broader themes because many commenters discussed training programs on several levels (i.e., department, county, state, federal) that together, created a form system for supporting their competence and mental models over time rather than a component of their department culture. We identified three codes (Table 7) based on commenters' concerns about the overall content and quality of existing training.

Many responses emphasized the content, frequency, and design of training courses, asking questions such as: (1) When was the last time the firefighter(s) involved [in the incident] were evaluated for skills performance? (2) How are officers and incident commanders trained and evaluated? (3) Is live fire training a regular occurrence? and, (4) Did members have training and evaluations on realistic scenarios?

To illustrate, Commenter 19 said investigators can consider "Examining the training that the fire department personnel received and if there was a chance to practice what was trained (e.g., had a FD practiced Mayday incidents and the use of rapid intervention crews)." Several comments focused on the availability of specialized training such as modules to assist with stress management, situational awareness, and selection and use of PPE during a response. Responses also touted the perceived value in scenario-based or live-fire training being available that aligned with real operational conditions. In a less common callout, commenters discussed whether training included department-specific SOGs/SOPs, connecting this inclusion to additional opportunities to read and use these procedures. Several commenters expressed that training around communication such as language, misunderstandings, radio bandwidth, and information sharing, could be more detailed.

More seldomly, responses homed in on the competency and certification of trainers and quality of the training to adequately prepare firefighters. Some comments cite gaps in current LODD reports, noting they do not provide a complete picture of the incident. Specifically, one comment noted, "While we do not wish to cast blame, we are failing to hold ourselves accountable and recognize critical shortfalls in firefighter training and fire department organization and tactics." The need to understand how training may have impacted performance and decision making was a thread across all training-related comments.

5. Discussion

Incorporating human factors elements into incident investigations is challenging, in part due to varying methodologies and occupational foci that could be deployed (Burban, 2016). The current results revealed fire service perspectives and priorities to consider during traumatic LODD investigations. Five primary themes emerged during the TQA, each containing three to six specific codes. Themes and underlying codes, supported by public comments, were often interdependent with each other. The RFI and HFACS taxonomy provided conceptual clarity for distinguishing codes within common elements such as department culture (e.g., psychological safety) and operational systems (e.g., resource management). Previous research in safety and risk management has demonstrated similar findings, showing a cyclical pattern of external, organizational, and individual interactions (Zhang et al., 2025). Consequently, even though we grouped human factors elements and codes into specific areas, investigators and fire departments may consider human factors elements other than those discussed here. This discussion lays the groundwork to begin exploring why and how some of these elements may be considered during traumatic LODD investigations.

Table 7
Training and Education Codes across Public Comments.

***Training and Education* Code**	**References (#)**	**Operational Definition**
Training focus and design	9	Training includes stress management and decision making to recognize and respond to acute stress during operational decisions.
Quality/Trainer Competency	4	Effectiveness and qualifications of trainers, curriculum, and delivery.
Inclusion of SOGs/SOPs	4	Training in the application and adherence to operating procedures.

5.1. Assessing department culture

Department culture emerged as an overarching element to consider. Within the fire service, department culture is often described in terms of the normalization of deviance (also normalization of risk), a process where unsafe practices gradually become accepted as standard behavior (Sedlar et al., 2023). Colloquially, fire service leaders have described normalization of deviance as safety shortcuts to save time (Cavnor, 2018). To date, specific references to department culture have been largely absent from the program's traumatic LODD reports; however, a recent report (NIOSH, 2025c (in press)) included department culture and more specifically, management development and accountability of SOGs/SOPs, as a recommendation to prevent safety shortcuts in the field. Previous research has supported this sentiment. Haas and Orstad (2025) presented evidence that public health and safety leaders who actively develop, communicate, and model organizational procedures can positively influence worker trust and safety behaviors related to PPE use. The authors also connected leadership communication practices to organizational culture within participating fire departments and healthcare entities.

Other research has consistently shown that communication and worker engagement are positive indicators of culture and can predict safety behaviors (Davis et al., 2020; Haas, 2020; Haas et al., 2024; Haas, Hoebbel, & Yorio, 2020; Smith et al., 2024; Taylor et al., 2019). These studies used surveys (e.g., NIOSH Organizational Climate Survey and Drexel's Fire Service Organizational Culture Survey [FOCUS]) that assessed several codes that also emerged in this study (e.g., management commitment to safety, crew-level safety norms and communication, training adequacy and other resources).

Moving forward, investigators might ask departments for a deidentified summary of previous culture assessments (if applicable) to consider with the investigation's contributing factors. Alternatively, investigators could use a short safety climate survey to help corroborate contributing factors. There are several short survey questionnaires that have been adapted to include psychological safety, a code within this current theme (Dollard & Bailey, 2021; Huang et al., 2017). If a survey is not feasible, investigators may use previously validated items to draft probes to use during witness interviews. Because a drift in culture can occur over time, a snapshot of safety climate might not present a comprehensive representation of the department culture; however, it is one data point to consider.

5.2. Integrating fatigue and other Core elements of Total worker Health®

Another human factors element consistently noted was worker well-being, or TWH. Previous research has highlighted the roles that stress, fatigue, and mental workload can have on occupational incidents (Dekker, Cilliers, & Hofmeyr, 2011). Considering these human factors elements may help determine the full extent of a firefighter's cognitive workload during a response.

5.2.1. Fatigue

The prevalence of fatigue throughout the comments was not surprising, considering that sleep deprivation has been shown to increase human error and subsequent occupational disasters and injuries (Joffe, 2006; Elliot & Kuehl, 2007). Previous research has assessed sleep quality among firefighters on various shift schedules (i.e., 24on/48off; 48on/96off; and Kelly) using the Pittsburgh Sleep Quality Index (Billings & Focht, 2016). These researchers found that the 24on/48off schedule was associated with better sleep quality and firefighters who work a second job experience significantly poorer sleep quality than those who do not. FFFIPP trauma investigations have recently acknowledged and discussed potential sleep deprivation from working shift schedules (NIOSH, 2025d).

Investigators obtain information like department shift schedule, overtime worked, and secondary employment when relevant during an investigation (e.g., fallen firefighter was a volunteer) but do not deploy validated fatigue measures. Although information gathered from witness interviews is subjective, it might be useful to include questions about observed signs of fatigue or stress. Further, if participating departments track data points around hours worked, sleep between shifts, and an estimated measure of cumulative fatigue, it may help to share this information with investigators to proactively identify fatigue as a risk factor. Since fatigue can be influenced by personal and organizational factors, applicable updates to SOGs/SOPs (e.g., shift schedules) may be another aspect to discuss with fire departments.

5.2.2. Other TWH elements

In addition to fatigue, fit-for-duty and resilience were discussed among commenters. Cognitive overload can impede workers' abilities to effectively respond in dynamic work environments, such as an active fire (Jozani et al., 2023). Fire service associations and partners have recognized the risks associated with cumulative exposure to traumatic incidents, calling for better surveillance and training focused on behavioral health and well-being (First Responder Center for Excellence, 2025; International Association of Fire Fighters, 2025). Therefore, considering exposure during previous incidents and personal and work-related stressors may be insightful during investigations. Commenters provided examples, one being the number of high-stress incidents experienced in the past month, including traumatic calls or personal stressors, as reported by others during witness interviews or ascertained from department call logs. Investigators can also ask witnesses if the firefighter appeared overwhelmed, confused, or unable to process information during the incident.

Fit-for-duty including cardiovascular fitness and return to work assessments were also discussed throughout the comments. Many comments emphasized the value of fit-for-duty programs and how to improve their deployment and integration into after-action reviews. Although current FFFIPP traumatic reports do not assess or comment on specific department wellness programs, some FFFIPP medical reports discuss the perceived value of workplace wellness plans if contributing factors align with general health and wellness (e.g., see NIOSH, 2025e, NIOSH, 2025f).

Human factors elements that encompass TWH may not be relevant for every investigation. However, having a short checklist available during interviews and document reviews (e.g., hours worked, signs of fatigue, recent exposures/stressors, fit-for-duty status) may be useful for investigators. Other department tools such as routine check-ins, fit-for-duty screenings, and peer support programs could also provide useful data points for investigators to collect and consider.

5.3. Improving communication and training in crew dynamics

Training and communication, specific to crew dynamics and operational safety, was frequently mentioned. Firefighter training modules tend to focus on technical skills and tactile responses; however, in real-world fire scenarios, failures in communication are a common cause of firefighter deaths (Willing, 2020). Analyses of FFFIPP contributing factors support this assertion (Kunadharaju et al., 2011; McDevitt, 2017), particularly when it comes to dispatch and Mayday communications (e.g., NIOSH, 2025g, NIOSH, 2025h). Similarly, Bearman and Bremner (2013) showed that poor communication from commanders results in inadequate decisions among firefighting crews. Communication as a consistent contributing factor to firefighter fatalities underscores the purpose of soft skill training like inter-crew communication, trust, and conflict management (Willing, 2020).

In addition to gaps in perceiving and responding to communication actions during an emergency, the perceived ability of crew members to speak up on the job was also mentioned. This pattern was not surprising, considering that training around power differentials and how it affects communication has been recognized as a significant factor in avoidable airline crashes, informing the development of crew resource management programs adapted for the fire services (Jahnke, 2016). These programs have become a standard training for some personnel to enhance psychological safety (e.g., teaching individuals how to question decisions in a hierarchical environment) and could be considered by investigators, if applicable.

Broadly, a more holistic assessment of fire department resources may be important to tie into other human factors elements. For example, Dixon (2015) argued that, if a department has reduced staffing, training, equipment, and funding, it can lead to firefighter complacency and poor decision making. Currently, trauma LODD investigations collect training requirements and logs from participating departments to understand technical and tactile skill development. Discussions around other types of training (e.g., emotional intelligence, communication practices, leadership, conflict resolution, etc.) are not included. If offered, it may be helpful for investigators to know these training offerings to more effectively assess and address communication and training issues during an investigation, if applicable.

5.4. Understanding and identifying gaps in decision making

Organizational and operational decision making was a complex theme that emerged across responses. Comments focused on incident details that may affect situational awareness and subsequent decision making, partly because disrupted situational awareness has frequently contributed to LODDs (de Carvalho et al., 2018; NIOSH, 2025d, NIOSH, 2025i). However, comments also noted the shift in emergency response landscapes, requiring increased cognition and faster responses. This sentiment is supported in recent literature proposing updated situational awareness methods for firefighters (e.g., Dos Santos & Son, 2024; Oliveira et al., 2019; Rezaeifam, Ergen, & Günaydın, 2023).

Many situational awareness and naturalistic decision-making frameworks exist, some of which have been developed with input from firefighters to inform how experienced commanders respond under pressure to uncertain and changing environments (Klein, 1993). Primary methods used to assess decision making include cognitive task analyses and applied cognitive task analyses (ACTA; Militello & Hutton, 1998; Klein & Hoffman, 2008). ACTA tools have been developed by the Navy Personnel Research and Development Center and consist of task diagrams, knowledge audits, and simulation interviews (Militello et al., 1997). More recently, researchers have focused on goal-directed task analyses (Rezaeifam et al., 2023) to determine firefighter's goal-decision-situational awareness structure.

Reliable deployment of these methods requires specialized training in cognitive science. However, investigators may be able to integrate some of these tools into their traumatic LODD investigations to inform not only how firefighters think (their strategies) but also what they think about (the content) during a response. Specifically, an ACTA consists of knowledge audits, task diagrams, and simulation interviews (Militello & Hutton, 1998) for which aspects can be adapted and integrated into the witness interviews. Table 8 shows an example of how these methods could be applied in fire service settings. As illustrated, there is already

Table 8
Possible Overlap of ACTA and Witness Interview Techniques.

ACTA technique	Application in LODD investigations	Example probes/tasks
Knowledge audit	Investigators could ask questions during witness interviews that mirror a knowledge audit of an ACTA to help understand key points of deviation. Responses would be observed or anecdotal.	• What was the first thing the crew noticed upon arrival? • Describe any visual or auditory cues noticed. • What was the hardest part or moment of the response?
Task diagram or map	Traumatic LODD investigations develop detailed timelines. Additional probing could be used to understand when poor decisions are made.	• Can you break [this task] down into several steps or subtasks? • Of these steps, which requires difficult cognitive skills?
Simulation interview	The actual incident is discussed with witnesses to try and identify cognitive processes during the incident, rather than providing a simulated scenario.	• Probes may focus on past and future incidents; big picture details; opportunities for future improvision; perceived self-monitoring; anomalies; and equipment difficulties.

some overlap between ACTA techniques and LODD witness interviews.

One possible outcome of incorporating methods to better understand cognitive processes is the eventual development of firefighters' mental models during a response. The notion of developing and supporting shared mental models among responders was evident in the responses. One comment noted that in healthcare, a safety-process checklist is used before any procedures to help create a shared mental model with the team, ensuring all are aligned with the goals of the procedure and prepared if complications emerge. However, before developing a checklist like this for firefighters, more focused cognitive questions may need to be asked during traumatic LODD investigations, as described in Table 8. Eventually, workers' decision-making requirements can be used to focus behavioral interventions or training (Klein, 2014), with materials oriented around the barriers and difficulties that workers experience while making decisions.

5.5. Limitations

Although the 33 public comments offered several human factors elements that may be considered in future investigations, there are limitations to the data and methods to consider. First, these responses, while elicited on a nationwide scale, represent a convenience sample of fire service partners and advocates who saw the RFI and chose to provide a public response. Similarly, although we provided an enumeration of codes, these numbers do not represent a measure of importance as the distributions are not generalizable. It is specific to the commenters who responded to this request for information. Disadvantages of convenience sampling, most notably sampling bias, can be considered when interpreting the feedback and determining next steps. For example, respondents (e.g., fire departments, academic institutions, and associations) may have had different motivations for their selection and advocacy for certain human factors elements. Comments may have also varied based on fire department size and experience, geographic location, personnel, and other resources that should be considered when studying human factors elements during an unfolding incident.

Additionally, while the RFI provided an initial umbrella framework and hence, structure to our analysis, it could have unintentionally restricted the conceptualization of overarching themes. While we consciously introduced inductive processes when coding to umbrella themes, our decisions to consolidate subcodes (i.e., fit-for-duty) was an outcome of our analytic determinations rather than objective measures or observations. It is possible that if we did not have an initial organization of themes, results may have been coded differently. However, these themes were already identified as being of central importance to the fire services and may have emerged similarly regardless. Also, the RFI only sought comments about human factors elements and not other technical aspects of traumatic LODD investigations (e.g., scene size up and risk assessment), which are more notable to our partners. It is possible that different organizations may have responded if the RFI was broadened to other priorities in the fire services.

Further, while the analysis relied on an established thematic analysis process (Braun & Clarke, 2006, 2022a, 2022b) and included subject matter experts to help assess and finalize the codebook, researcher bias must be considered. A multidisciplinary coding team was used to enhance contextual understanding of the comments to best capture perceptions of the fire service; however, the different perspectives may have also introduced unintended bias in code assignment or emphasis within the primary themes. This is especially important in considering the involvement of firefighters in the analysis, where their perspective may have carried more weight in final decision making. Future work may triangulate perspectives and feedback with other fire service stakeholders.

5.6. Practical applications

This discussion was not exhaustive of all the codes that emerged across comments. However, regardless of the human factors elements initiated, the general investigation process is likely to be similar: investigators can ask "Why?" until root causes are revealed. According to the Federal Aviation Administration, this inquisitive process supports a factual, standardized approach of assessing causation without assigning blame (FAA, 2023). The answers to the "why's" may be seen as symptoms and not causes of failure (Dekker et al., 2011).

We recognize that some of the methods and ideas discussed in this paper require specialized training, and we do not suggest that all investigators can deploy human factors tools with the same rigor or impact as a trained professional. However, some of these suggestions can serve as a starting point in the fire services to inform the use of updated, specific tools and processes to better understand: (1) human factors elements that could be considered during traumatic LODD investigations, and (2) interdependent relationships between these elements and their role in identifying latent root causes that are difficult to detect. Specifically, it is clear from the feedback that a holistic view of human factors exists, which may impact the selection and deployment of human factors elements – that is, because of the interdependent nature of some elements, there may be a path to strategically assess a few at a time. At the same time, however, investigators can be aware of the potential impacts that human factors elements may have on one another if only some are being assessed.

5.7. Conclusion

In this paper we analyzed public comments to inform future empirical assessments of human factors elements. Although it may be impossible to eliminate all hazards faced by firefighters due to their inherent and emerging risks, there is space to advance how investigations are completed, including what and how human factors can be assessed. Currently, a comprehensive assessment of all possible human factors is not practical given the time it would add to a traumatic LODD investigation. Future research may consider drilling down to assess more specific codes that emerged across responses. For example, fatigue was overwhelmingly emphasized in the feedback and may warrant more immediate and detailed attention to understand how it could be objectively assessed. To this end, quantitative research with a larger sample size to help focus elements and draft instruments could be a next logical step before collecting additional qualitative information about these elements. Finally, consultation and reviews of human factors tools and frameworks from the aviation industry and military settings could inform how human factors elements are integrated into investigation protocols.

5.8. Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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