Industrial Firefighting Preparedness: A Literature Review

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***Abstract*—This study systematically reviews the state of industrial firefighting preparedness by synthesizing research published between 2004 and 2025 across multiple domains, including regulations, training methods, technology integration, and human behavior. The analysis draws on academic sources, policy documents, and sectoral case studies, covering industries such as oil and gas, chemicals, healthcare, logistics, and public infrastructure. Findings indicate that although fire safety regulations have evolved in response to catastrophic incidents, enforcement remains inconsistent across regions, and performance-based design frameworks face challenges of expertise asymmetry. Training effectiveness is significantly enhanced through immersive technologies like virtual reality, yet issues of long-term skill retention and practical applicability persist. Sector-specific preparedness strategies demonstrate the critical role of modern building design, community participation, and digital innovations such as BIM-based fire management systems. Human behavior emerges as a decisive factor in fire response, underscoring the need to integrate social science perspectives into safety planning. Collectively, the review highlights the importance of holistic, adaptive, and cross-sectoral approaches to mitigate fire risks, enhance resilience, and build sustainable safety cultures within industrial environments**

***Index Terms*—Fire safety, firefighting training, industrial preparedness, occupational safety, virtual reality, fire behavior, risk management**

I. INTRODUCTION

Fire incidents have historically been among the most destructive hazards in industrial contexts, causing significant loss of life, severe property damage, and long-term economic disruption. With industrial sectors handling highly flammable substances, crowded facilities, and complex operations, the risks of fire are amplified. Despite advances in safety technologies and regulations, catastrophic fires in hospitals, factories, chemical plants, oil and gas facilities, and logistics centers demonstrate persistent deficiencies in preparedness [1].

Eventually we have seen across the globe, global calamities as the Grenfell Tower fire incident in the UK and with the recent times of various explosions from refineries across the world that indicates failures due to systemic gaps in controlling the fire disaster. Similarly, in India, our industrialized States are constantly reporting large incidence with fire accidents, where large chemical hubs are fire vulnerable destinations, as in Surat in Gujarat. These issues find social clogances and dysfunctional environments in both developed countries and developing countries in terms of enforcement gaps in inspections, training short falls, and behavioral contributory factors towards fire associated deaths and injuries [2].

Preparedness in firefighting is not just about compliance. It's about ensuring all workers, managers as well as emergency responders are equipped with the knowledge, skills, and abilities to responsibly and effectively manage a fire event when it occurs. Preparedness for industrial firefighting includes requirements around physical preparedness, regulations and codes of practice, technology and skills, and behaviour. This review presents a landscape analysis of the status of physical, regulatory, technology and skills and behavioural preparedness across different sectors identifying capacity, capabilities, strengths and weaknesses and future research needs [3].

II. LITERATURE STRATEGY

This review follows an established systematic review process to identify, analyze, and synthesize research into understanding firefighting training and preparedness. Below is an overview of how searches of academic and grey literature on firefighting training and preparedness were undertaken. Academic

databases (PubMed, Scopus, Web of Science and Google Scholar) as well as grey literature, e.g., government, industry safety report or sectoral guidelines, were searched for relevant literature. The inclusion criteria were:

Timeframe: Studies published between 2004 and 2025.

Scope: Research focused on firefighting training, preparedness, industrial fire safety, or fire risk management.

Methodological Diversity: Both qualitative and quantitative studies, systematic reviews, simulation research, case studies, and policy analyses were included.

Geographical Spread: Studies from developed and developing countries were considered to capture a global perspective.

From an initial pool of more than 7,000 articles screened (Barati Jozan et al., 2023), the final pool was a small selection of research papers focused on regulatory change (Mamatha et al., 2023; Spinardi et al., 2025), training effectiveness [4]. (Wheeler et al., 2021, Grabowski et al., 2020), technologies implementation[5] (Kim et al., 2023), and behaviour relating to fire emergencies (Haghani et al, 2024; Bayat, 2020) [6].

Conceptual Framework

Firefighting preparedness across industrial sectors can be conceptualized as the interaction of regulatory structures, training methods, technological integration, and human behavior. Regulations provide the foundation, but without proper training, compliance remains weak. Technology enhances training by facilitating realistic simulations, optimizing training scenarios, and ensuring real-time data integration. Human and organizational factors, which impact decision-making during emergencies and represent the safety culture in an organization, are the mediators of effectiveness. These components collectively influence the overall preparedness level, which is how prepared the industries are to effectively prepare in order to reduce fire risk, mitigate damages, and enhance resilience.

Figure of Conceptual Framework

III. METHODOLOGY

A systematic literature review is applied in this study to assess the impact of firefighting training and preparedness practices in different industrial sectors. To do this, academic journal articles, commentary articles, policy papers, and case studies published between 2004 and 2025, were identified using Scopus, Web of Science, PubMed, and Google Scholar. Grey literature including safety regulations and reports, were also considered for contextual information.

Review of Literature

Evolution of Fire Safety Regulations and Standards

Current fire safety regulations are reactive strategies following the course of disaster; these regulations have slowly established minimum safety criteria to help protect both people and buildings (Mamatha N. et al., 2023). Similar to urban sustainability issues where disjointed and deprecated frameworks are blocking progress (Schellenberg et al., 2020), fire safety codes have to consider the dual challenges of increased urbanization, as well as new materials and high-rise

construction [7]. A movement is developing around performance-based design (PBD) globally to allow for innovation but there may be potential for increased regulatory oversight based on the "expertise asymmetry" that exists between those deciding on design and construction and those who enforce codes (Spinardi et al., 2025). Contexts in Brazil, Spain, and India show both the challenges and opportunities: Brazil's failure to establish state codes creates waste but the opportunities for leveraging what may contribute to accelerate the development of national codes (Rodrigues et al., 2017); Spain shows the possible "ideal" code versus the existing code and the risks illuminating inadequate protection [8]. (Osácar et al., 2021); India's weak regulatory enforcement model located within an urban environment warrants consideration for more stringent regulations, technology based regulations, and community awareness / engagement around fire safety[9] (Kannan et al., 2025); Tamil Nadu's adaptation of its fire and rescue services demonstrates good development in adapting to changing conditions (Govindaraj et al., 2024). Some overall analyses suggest that while present methods of life safety building are not ideal, they can and will continue to be better, relying on a planned/multi-faceted and integrated approach, including reliable enforcement, regulatory and monitoring systems, good regulatory enforcement, public commitment and action relating to awareness and compliance, and technological innovation[10] (Kodur & Kumar, 2019). There are many detailed recommendations of new regulation, such as Australia's regulation of fire risk cigarettes. In contrast, regulatory failures (e.g., Grenfell Tower) have highlighted discrete authorities, reduced local capacity and coordination and require a level of national guidance and competence [11]. (Benso et al, 2022). Stiffness in sub-surface locations reflected the same forms of limitations on thinking about and taking on innovation, but rather demonstrated that standards should be flexible, but uncompromising (Moreau et al, 2021). What lies at the thin end of this reliance on fire resistance testing is not so much the proxy itself, but that fire resistance testing become codified as a proxy for safety whilst losing generations of contemporary fire science [12] (Spinardi et al, 2024). Collectively, these studies illustrate that the development of fire safety regulations tends to represent the tensions between prescriptive regulatory traditions and normative behaviors accepting performance and above, centralized versus deliberatively decentralized governance and regulatory balance, and historically derived inertia regarding emerging science, with the future of regulation having an uneasy path which has the capacity to bridge the existing gaps in expertise, respond regulatory standards to contemporary risk framework and internalize the technological and community-based innovations.

Summary Table: Evolution of Fire Safety Regulations and Standards

Author(s) & Year	Focus/Context	Key Findings	Implications
Mamatha N. et al. (2023)	Historical evolution of fire safety codes	Regulations are reactive, emerging after major fire disasters; dynamic but challenged by new materials and high-rises	Need for proactive, innovative, and continuously updated codes
Schellenberg et al. (2020)	Urbanization & wastewater management (India)	Centralized systems fail sustainability challenges; regulatory inconsistency hampers decentralized solutions	Parallel to fire safety: need holistic, adaptive, context-specific frameworks
Spinardi et al. (2025)	Performance-Based Design (PBD) in fire safety	Shift from prescriptive to PBD; regulators face "expertise asymmetry" with engineers	Suggests professional self-regulation, but trust and maturity issues remain
Rodrigues et al. (2017)	Brazil's fire safety regulations	Fragmented state-level codes create inefficiencies; common technical base exists	Unified national-level code would streamline enforcement and reduce costs

Author(s) & Year	Focus/Context	Key Findings	Implications
Osácar et al. (2021)	Fire safety regulations in Spain	Large gap between "ideal" framework and current practices; inadequate risk mitigation	Urgent reforms needed to align legal frameworks with real-world risks
Kannan et al. (2025)	Indian urban residential fire safety	Weak enforcement, rapid urbanization, high density reduce effectiveness	Stricter compliance, tech adoption, and community engagement required
Govindaraj et al. (2024)[13]	Fire & Rescue Services in Tamil Nadu	Services evolved from rudimentary to advanced with equipment, training, 330+ stations	Demonstrates successful modernization and adaptability in Indian context
Kodur & Kumar (2019)	Global fire protection strategies	Existing measures inconsistent; safety levels unquantified	Propose integrated framework: stronger codes, awareness, technology, enforcement
Ghassempour et al. (2022) [14]	RFR cigarette regulation, Australia	Policy reduced smoking-material fires by 8%; major decline in severe incidents	Evidence-based targeted regulation effective in risk reduction
Benso et al. (2022)	Grenfell Tower & UK planning failures	Local discretion, lack of national guidance, austerity weaken fire oversight	Stronger legislation and clear guidance essential for consistency
Moreau et al. (2021)	Underground fire safety regulations (France, Switzerland, Hong Kong)	Rigid rules constrain innovation and stakeholder consensus	Flexible, pragmatic codes needed without compromising safety
Spinardi et al. (2024)	Role of fire resistance testing	Standard furnace tests entrenched but poorly represent real fires; hinder modern science	Need shift to fire science–driven approaches for innovative solutions

Firefighting Training Methods and Techniques

Firefighting training is increasingly recognized as a multidimensional learning experience since it encompasses physical conditioning alongside information sharing through technological advancement for preparedness and safety. Ubieto-Artur et al. (2025) describe that theoretical education, combined with a more immersive simulation that made domestic fire drills more realistic, increased long-term awareness, attitude and behavior. Bęś et al. (2024) described the seduction of incorporating active methods (i.e. gamification, demonstration, and V.R.) blended in the training of high-risk industries [15]. Smith et al. (2024) describe strong associations with enhanced safety training, safety knowledge, and appropriate use of PPE, with assumptions that knowledge generation was leading to knowledge use, and an increased use of safe behaviors [16].

Physical fitness is also a consideration. Chizewski et al. (2021) demonstrate that high-intensity functional training shows significant improvements in endurance, strength, and firefighting-specific performance measures while Leary et al. (2020) report that although their occupational exercise program produced minimal physiological improvements, the program participants developed teamwork skills and saw positive lifestyle changes in their wellness [17], [18]. In addition, Horn et al. (2019) demonstrate that, aside from ambient temperature, the workload intensity associated with live-fire training tasks drove participants' physiological strain, which may provide vital information for safely constructing a training program [19].

Technological developments, particularly in the area of virtual reality (VR), have significantly influenced how people learn. Jeon et al. (2021), state that meaningful interaction (not realness) matters most in

VR learning, and Wheeler et al. (2021), cite VR as helpful for particular complex tasks, such as search and rescue [20]. Grabowski et al. (2020), discuss the broader evolution of VR and its ability to imitate dangerous and potentially harmful scenarios, such as a confined-space fire, and Engelbrecht et al. (2019), outline the benefits of VR in safety and cost of training scenarios, but highlighted concerns regarding skills transferability and acceptance of the technology [21]. These studies also show that effective firefighter training should adopt a more comprehensive approach that balances immersive technologies, organization of safety training, physical fitness, and live-fire training. VR and gamified approaches were shown to offer safe and innovative learning opportunities for firefighting staff, however, physical readiness and correct use of equipment still needs to be prioritized. Equally, firefighter training must be adaptable, evidence-based, and multifaceted to promote operational resilience in high-risk contexts.

Summary Table: Firefighting Training Methods and Techniques

Author(s) & Year	Focus/Context	Key Findings	Implications
Ubieto-Artur et al. (2025)	Domestic fire safety drills, Spain	Combining theory with virtual & physical drills improved long-term awareness and behavior	Immersive simulations + instruction enhance safety education; replicable in other prevention schools
Bęś et al. (2024)[15]	Training in high-risk industries	Active methods (gamification, VR, discussions) most effective when combined	Training should be well-planned, multi-method, and part of sustainability strategy
Smith et al. (2024)	Firefighter PPE use & safety behavior	Structured training → better safety knowledge → safer PPE practices (PASS, SCBA, inspection)	Strong training ensures correct PPE use and reduces injuries/fatalities
Chizewski et al. (2021)[18]	High-Intensity Functional Training (HIFT) for recruits	Daily HIFT improved fitness, endurance, and firefighting performance	Fitness-focused training boosts both health and firefighting-specific abilities
Jeon et al. (2021)	VR controller design in training	Realism alone didn't improve experience; interaction effectiveness mattered	VR tools must balance realism and usability for effective learning
Wheeler et al. (2021)	Systematic review of VR firefighting training	VR effective for complex scenarios (search, rescue, command) but field still emerging	VR is promising but needs more empirical validation and guidelines
Grabowski et al. (2020)	Evolution of VR in professional training	VR replicates hazardous/confined fire scenarios safely	VR is transformative for dangerous, otherwise impossible real-life training
Leary et al. (2020)[17]	Occupational exercise program	Limited physiological gains, but improved teamwork and lifestyle	Exercise programs aid long-term health behavior and team cohesion
Engelbrecht et al. (2019) [21]	SWOT of VR in firefighting	Strengths: cost, safety, realism; Weaknesses: limited fire apps, uncertain skill transfer	Need tailored VR apps and further research on real-world applicability
Horn et al. (2019)[19]	Physiological responses in live-fire training	Core temperature/HR similar across training types; workload > ambient heat	Training design should consider workload intensity, not just temperature

Industry-Wise Fire Preparedness Strategies/ Fire Preparedness Strategies in Companies

Given the increasing size and complexity of fire risks in modern society, strategies for fire preparedness related to different industries and companies are

becoming more important. Chirag, Chandran, and Bhati (2021) evaluated the impact of modern technology, building design, and preparedness on mitigating hazards by referencing case studies of large fire events that occurred in India, including high-rise buildings and hospitals during COVID-19. Chirag et al. (2021) outlined what needs to be in place, sighted awareness of occupants and organizational preparedness, lack of hazards through design and safety systems, and the development of comprehensive safety systems across as many risk areas as possible [22]. Similarly, Rathod, Desai and Kharya (2023) recognized the need to explore fire threats in India's industrial, and residential, sectors, referencing the seriousness of the fire risk in India as identified by the National Crime Records Bureau (NCRB of India). Rathod et al. (2023) measured the average fire risk in India as 8.04% and emphasized that the western states of India are especially vulnerable. Regional studies highlight areas of high fire risk in the state of Gujarat and reference the many chemical facilities in Surat. Rathod et al. (2023) suggest that there are also site hazards present in this area and have identified that stricter fire protection systems are required in these industrial regions.

In addition to infrastructure, preparedness must include public engagement and training. Menzemer et al. (2024) show through survey and interview data that fire evacuation training is statistically significant in enhancing perceived preparedness, awareness of risk, and personal responsibility. However, they did highlight some limitations of using drill training exercises, particularly the lack of immediacy and seriousness to the training [23]. As called out by Menzemer et al. (2024), fire drill training and training in general should promote education drawn from a young age and training that promotes designed effectiveness to elicit practical behavior [23]. Further to this wider geo-political context, Aggarwal and Dwivedi (2022) review literature in regard to events of fire in India. They report a wider and growing threat of forest fires, which may affect ecological balance and incomes. Aggarwal and Dwivedi (2022) highlight the need to adopt pro-active risk management and community protection approaches and integrate ecological mitigation and community protection strategies [24]. Akhtar et al. (2021) focus on effective fire disaster management in developing countries such as Bangladesh, where the success of fire disaster management is reliant upon the involvement of and engagement by community members. By engaging community members attitudinally and practically, community members can be at the forefront of the preparedness phase, response phase, and recovery phase of a fire disaster.

Industry-specific analyses provide more context. Wu et al. (2023) focus on long-term care institutions in Taiwan to demonstrate how defense-in-depth fire protection greatly limit the fire duration and loss of life and will be even more critical as society ages [25]. Kim et al. (2023) consider fire preparedness in large, complex buildings by developing a BIM-based Smart Fire Rescue Management (SFRM) systems that allows static building information to be integrated with real-time information about fire and response actions that firefighters can take. Jiang et al. (2023) consider chemical industry parks and proposed an advanced modelling approach to determine the risk of fire and also locations for fire stations to consider location of hazardous chemicals and domino effects as part of emergency planning [26]. Likewise, Jatmika et al. (2024) evaluates fire preparedness in the oil and gas sector using FERRAT and finds that while fire preparedness is now satisfactory, it needs to continuously improve through simulations and timely policy initiatives.

Variations in industries have unique considerations. Kormych et al. (2022) exemplified the maritime industry of Ukraine whether this industry operationalized during armed conflict protections. Fortunately, they offered solutions to address the stressed ports and shipping infrastructure in the context of missile attacks and blockades while also reflecting on the conceptualization of resilient patterns in occupied and contested spaces [27]. Ding et al. (2020) documented fire safety challenges in China's public entertainment sector, specifically as their industry facilitated modern-day flammable materials and improper storage contributing to fire incidents occurring conventionally when venues were crowded [28]. Ding et al. (2020) also emphasized a call for fire safety improvement policy and framework, for future practice, which encompassed all of the following limited recommendations for improving: strict standards regulations, improved exits practices of locations, and regulations for with combustible materials. The end goal intended to better improve fire

safety in venues rampant with hosting populations [28].

Summary Table: Human Factors and Behavioral Aspects in Fire Emergency Response

Author(s) & Year	Industry/Context	Key Findings	Implications
Chirag et al. (2021)[22]	Buildings (India)	Modern tech + building design critical; COVID-era fires exposed weaknesses; occupant awareness essential	Robust fire safety systems and better organizational preparedness needed in urban and rural India
Rathod et al. (2023)	Industrial & residential (India)	NCRB: 18,450 incidents, 17,700 deaths; western states most vulnerable; Gujarat (chemical industries) at high risk	Industrial hubs require stricter, tailored fire protection systems
Menzemer et al. (2023)	Public evacuation training	Training increases perceived preparedness, familiarity, and responsibility; drills often lack urgency	Early-age education and engaging drills can improve real-world responses
Aggarwal & Dwivedi (2022)	Forest fires (India)	Fires disrupt ecosystems and livelihoods; peak March–June	Proactive strategies needed: ecological preservation + community livelihood protection
Akhtar et al. (2021)	Global disaster management (Bangladesh focus)	Community-level participation key; policy alone insufficient	Grassroots involvement fosters resilience and risk reduction culture
Wu et al. (2023)[25]	Long-term care institutions (Taiwan)	Defense-in-depth protection reduced fire times (1 hr → 15 min) and casualties	Layered safety strategies can reduce death rates to zero in care facilities
Kim et al. (2023)	Large complex buildings (BIM)	Developed BIM-based Smart Fire Rescue Management (SFRM); integrates static & real-time fire data	Digital tools can expedite disaster response, but need refinement
Jiang et al. (2023)[26]	Chemical Industry Parks (China)	Risk model + fire station location optimization using Monte Carlo + TOPSIS	Scientific planning improves fire station placement and risk coverage
Kormych et al. (2022)[27]	Maritime (Ukraine, conflict zones)	Ports damaged by strikes/blockades; shipping disrupted; legal gaps exposed	Maritime infrastructure highly vulnerable; requires resilient & legal safeguards
Ding et al. (2020)[28]	Public entertainment venues (China)	Main risks: flammable décor, poor storage of combustibles/explosives	Stricter material standards, regulated storage, and evacuation planning needed
Jatmika et al. (2024)	Oil & gas industry	Fire Emergency Response Readiness Assessment (FERRAT) showed satisfactory results overall	Continuous improvement via drills, policies, and systematic upgrades required

Human Factors and Behavioral Aspects in Fire Emergency Response

To advance the field in understanding human behaviour in fire emergencies for improved evacuation outcomes and fire safety plans, it is important to identify the major research in order to achieve this objective. Haghani et al. (2024) provide bibliometric evidence of the field, which identified 1,872 studies and 6,632 references dealing with human behaviour in fires (HBiF) and they note what is known regarding HBiF based upon their review of the academic corpus and they identified a number of gaps in our knowledge,

suggesting that further movement is a possibility for HBiF [29]. Their analysis comprised coverage of what has been accomplished so far, and it is noted that behavioural decision-making in evacuation models and safety planning remains the under-developed area(s) and they indicated important needs for more theoretical and practical development in this area. Similarly, Kuligowski et al. (2016), provided suggestions for where we can improve HBiF - in that they emphasized the need to engage other social sciences that can help improve HBiF research - and more specifically, Kuligowski et al. (2016) emphasized that unobservable psychological factors and contextual factors will not be investigated, especially pre-incident or post-incident factors, and to engage with qualitative research in sociology and psychology to improve HBiF research.

Sahebi et al. (2021) evaluate hospital fire evacuations in Iran and reflect on human, organizational, environmental, and ethical dimensions that shape outcomes in healthcare contexts, emphasizing that evacuation considers not only protocols, but also levels of preparedness, coordination, and values like empathy, trust, and accountability. Wang et al. (2021) use behavioral decision theories to analyze fire emergencies in an urban rail transit context and use prospect theory to illustrate how risk and loss perceptions shape emergency planning [30]. Their framework is derived from the Tianjin Rail Line 3 and shows how behavioral economics could improve rationality and psychological factors in decision making when in a high stakes emergency.

Advances in technology have also modified human elements' level of engagement with fire impacts and response. Gerges et al. (2022) reviewed smartphone evacuation decisions/guidelines relevant to high-rise buildings. Their findings demonstrated a clear user's preference for mobile technology, such as BIM and real-time sensors, to communicate and develop potentially personalized escape routes [31]. Wheeler et al. (2021) undertook a systematic review of firefighter training via VR. Their findings suggest immersive simulations could affixlong-term critical decision-making models regarding search and rescues while exploring the user experience and learning outputs [6]. Suparto et al. (2024) completed a meta-analysis comparing evacuation decisions. The review demonstrated that values, situated actions, demographics, and built environment interactions all influence the evacuation process contingent on what is perceived as the 'emergency' with residential, commercial, and industrial models reviewed.

We must also take a step back and reminder what resilience looks like at the community level. Dinić et al. (2023) exemplified both the key role that social capital, socio-economic factors, and even religious faith can play in how communities prepare for, respond to, and recover from fire disaster; this is not only significant within our understanding of a resilience model in terms of social and psychological aspects, and not only infrastructure based. Sasangohar et al. (2020) mentioned a more general and overarching view of disaster management through the lens of the COVID-19 experience; to the point of identifying there are human factors and ergonomics (HFE) that can be leveraged to lessen the impact of catastrophic, large-scale, sustained emergencies through coordinated action, informed communications and integrated training programs [32].

Author(s) & Year	Context/Focus	Key Findings	Implications
Haghani et al. (2024)[29]	Human behavior in fires (HBiF), bibliometric study	Analyzed ~1,900 studies and 6,600 references; identified trends, influential works, and gaps	Need stronger integration of behavioral decision-making in evacuation models and planning
Kuligowski et al. (2016)	Social science perspectives on HBiF	Psychological/contextual factors often ignored; pre- and post-fire phases understudied	Sociology/psychology + qualitative methods can enrich HBiF and improve fire safety strategies
Sahebi et al. (2021)	Hospital fire evacuations, Iran	Human, organizational, environmental, and ethical factors shape evacuation	Preparedness must go beyond protocols; empathy, trust, and accountability are essential

Wang et al. (2021)	Urban rail transit fire emergencies	Applied prospect theory; modeled decision-making under risk and uncertainty	Behavioral economics can make emergency planning more rational and psychologically attuned
Gerges et al. (2022)[31]	High-rise building evacuations, Egypt & UK	Strong support for smartphones delivering BIM + sensor-based evacuation routes	Mobile tech can bridge design and occupant safety, offering real-time tailored guidance
Wheeler et al. (2021)	VR-based firefighter training	VR effective for decision-making scenarios; user experience is central	VR is a safe, realistic tool for training but needs more empirical validation
Suparto et al. (2024)	Literature review on evacuation dynamics	Human responses shaped by decision-making under stress, spatial layout, demographics, infrastructure	Evacuation planning must integrate behavioral, spatial, and demographic insights
Dinić et al. (2023)	Community resilience to fire disasters	Social capital, socio-economic factors, and religious faith influence resilience	Resilience requires strengthening social/psychological resources, not just infrastructure
Sasangohar et al. (2020)[32]	Disaster management during COVID-19	Human factors and ergonomics (HFE) improve coordination, training, and PPE design	HFE principles can enhance adaptability and resilience in prolonged crises

IV. GAPS IDENTIFIED IN THE LITERATURE

While progress has been made in the current literature, there are still considerable gaps. Broadly, much of the research is uneven across areas of inquiry. For instance, a lot of the research has been on the areas of oil and gas and health, while other areas, like logistics, warehousing and accommodation, have little to no systematic research. There is a limited amount of studies that look longitudinally of virtual reality and gamified training approaches that, when looked at, do not alternatively examine long-term changes in behaviour. Pragmatic issues of mental preparedness and stress/emotion management have not firmly taken root as a part of bigger training trifecta, (they remain very important to on-their feet DECISION-MAKING) in contrast to more traditional forms of training facilitation [33]. As well there is limited to no research understanding the trainer/trainee interface (eg what does the trainer/co-trainer need to demonstrate as a competent instructor toward a trainee and the trainee may have some culturally innate and organizational context bias) which has some significance for the phenomenological interpretations gleaned about knowledge transfer effectiveness. Finally, all studies are largely completed in isolation and in limited areas, and don't often include any crossover comparisons, so may not permit any best or universal practice related to the industries.

V. FINDINGS

The review shows the challenge of industrial fire preparedness; its success relies on regulation, training, technology, and human factors. Regulatory migration from prescriptive standards or codes everywhere to performance-based design is troubling, and lack of enforcement practices and governance inhibits success. When we think about training the best studies included a fitness element with instructional elements that produced a VR enabled simulated training experience. This type of training produced the highest levels of awareness and preparedness in relation to safety practice and operational skill. The technological systems; BIM based fire rescue management systems (help managers of complex facilities prioritize) and device-based evacuation guidance are beginning to demonstrate the potential to play an important role to combine these aspects to reduce response times and synchronize actions, as appropriate, during multi - facility emergency responses. When considering human behaviours and other collective social aspects, human behaviours and factors exert an important influence on fire evacuation outcomes, and evidence suggests aspects such as empathy, trust, community resilience, and risk perception shape preparedness strategies and therefore challenge the effectiveness of fire safety systems (in managing fire safety situations). The review highlights examples from industries that

depend on fire in particular; chemical industrial hubs in India and coal mining (Taiwan institution for long-term care). These examples highlight the need for highly contextualized interventions that

Implications for Future Research and Practice

Looking ahead, future empirical and conceptual research into underrepresented fields like logistics, warehousing, and entertainment should be an area of focus as these fields are becoming more likely to be involved in an urban fire emergency due to rapid urban development and increased complexity in material holdings. Longitudinal studies are warranted to determine whether the immersive technologies of VR and integrated technology ultimately create meaningful change in behavior and lower incident numbers. Training should also include mental perspective, stress tolerance, and cognitive decision making in real or perceived high-stress circumstances. When discussing the definition of realism in the field of firefighting, the training should relate to doing the job as much as discussing the mental realities of performing the job. Practically, industry leaders need to try to learn what has been used in other sectors and combine the knowledge to provide fire prevention practices and protocols that rely on prescriptive and performance-based regulations, and methodologies to engage with the community. These initiatives should include technology as well. Overall, it is ideal to have global commonalities in fire codes with increased enforcement of the regulatory frameworks and enhanced professional personnel capacity to improve our preparedness. Practitioners should promote adaptive-training plans and thinking to utilize both new technology and culture, to ensure that our preparedness styles can be learnt and understood within their context and subsequently adapted and transferrable across contexts.

VI. CONCLUSION

Preparedness for industrial firefighting continues to be critical with the repeated experience of catastrophic fire events across the globe. Despite regulatory changes, technology improvements and training advancements that have improved safety measures occasioned by fire risk, global evidence exists that systemic deficiencies remain, particularly with enforcement, psychological preparedness, knowledge sharing across sectors and others. Based on the evidence summary, and its external validity across sectors, we conclude that integrated preparedness strategies of integrated governance, a variety of training options (including psychological practice), innovative technologies, and human behaviour are essential in fire understanding and risk mitigation and meaningful development of resilience. The idea that preparedness action to be taken in silos that are delivered in separate stages is ineffective when compared to preparedness frameworks that incorporate regulation, systems innovation, and are human-centric. If the identified gaps and research opportunities are successfully addressed and with integrated approaches that allow cross-sectoral collaboration, there exists a real opportunity across industries to minimize fire risks, protect human life, and contributing to resilience in organizations from future hazards.

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