

## **DEVELOPMENT AND IMPLEMENTATION OF AN EVIDENCE-BASED SAFETY TRAINING FRAMEWORK FOR UNESCORTED VISITORS IN A PETROLEUM REFINERY: A CASE STUDY OF THE CENOVUS LIMA REFINERY**

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### **Abstract**

*The petroleum refining industry operates in hazardous environments where effective occupational health and safety management is critical. Although comprehensive safety systems exist for employees and contractors, unescorted visitors remain vulnerable because of limited familiarity with site-specific hazards and emergency procedures. This study developed an evidence-based safety training framework for unescorted visitors at the Cenovus Lima Refinery, United States, using a framework-development research design. The framework integrated occupational safety management, adult learning principles, situational awareness, microlearning, and digital visitor management technologies through five sequential development phases. Findings identified key visitor hazards, including vehicular traffic, maintenance activities, electrical risks, emergency situations, and security threats. The framework incorporated risk-based visitor classification, targeted hazard-awareness training, behavioral safety controls, emergency preparedness, and a Visitor Management System linking training completion to badge authorization. The proposed framework provides a practical, scalable approach for improving visitor safety, strengthening regulatory compliance, and supporting organizational safety culture and zero-harm objectives in high-hazard industries.*

**Keywords:** *Occupational health, Visitor safety, Petroleum refinery, Microlearning, Situational awareness, Process safety, Digital access control*

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### **Introduction**

The petroleum refining industry is widely recognized as one of the most hazardous industrial sectors due to the presence of complex chemical processes, high-pressure systems, flammable materials, toxic substances, and extensive mechanical and electrical operations. Within such environments, Occupational

Health and Safety Management (OHSM) plays a critical role in safeguarding personnel, ensuring regulatory compliance, and maintaining operational continuity (International Labour Organization, 2024; Occupational Safety and Health Administration [OSHA], 2024). Over the past several decades, industrial safety management has evolved

from a reactive approach focused primarily on accident investigation and regulatory compliance to a proactive, systems-based framework emphasizing risk prevention, resilience, and continuous improvement (Hollnagel, 2022; Adikwu *et al.*, 2024). Contemporary safety philosophies such as Safety-II, resilience engineering, and human performance management advocate the identification and mitigation of latent hazards before adverse events occur, thereby promoting organizational learning and operational reliability (Hollnagel, 2022; Gultom and Erislan, 2025).

Despite significant advances in industrial safety management, a persistent gap remains in the protection of transient populations, particularly contractors, vendors, auditors, government officials, and business visitors who require temporary access to industrial facilities. Unlike permanent employees who undergo extensive safety training and become deeply integrated into the organizational safety culture, visitors often possess limited knowledge of site-specific hazards, emergency response procedures, and behavioral expectations (Everant, 2024; *Frontiers in Public Health*, 2025). Consequently, they represent a vulnerable group within refinery environments, especially when granted independent access to designated facility areas.

Previous studies have demonstrated that unfamiliarity with workplace hazards significantly increases the likelihood of unsafe behaviors, near-miss incidents, security breaches, and occupational injuries (OSHA, 2024; Everant, 2024). Even within non-process areas, visitors may encounter numerous hazards, including vehicular traffic, slips and falls, temporary maintenance activities,

electrical risks, emergency alarm systems, and proximity to operational units. Furthermore, major industrial accidents have shown that administrative buildings and visitor-accessible locations are not immune to the consequences of process safety incidents, particularly where toxic releases, vapor cloud explosions, or overpressure events occur (American Petroleum Institute, 2021; BakerRisk, 2024). Consequently, effective visitor safety management has become an important component of comprehensive refinery safety systems.

Regulatory frameworks and industry standards reinforce the necessity of providing adequate safety information to all individuals entering hazardous facilities. The Occupational Safety and Health Administration (OSHA) and Process Safety Management (PSM) requirements emphasize the obligation of organizations to communicate workplace hazards and safe work practices to employees, contractors, and visitors alike (OSHA, 2024). Similarly, industry guidelines developed by the American Petroleum Institute (API) underscore the importance of facility siting, emergency preparedness, and hazard communication in protecting both permanent and transient populations (API, 2021). These regulatory expectations have increasingly highlighted the need for structured visitor management systems that integrate safety training with access-control mechanisms (*Occupational Health and Safety Magazine*, 2024).

The challenge becomes particularly significant in the context of unescorted visitors. Unlike escorted visitors who remain under continuous supervision, unescorted visitors are authorized to move independently within designated non-process areas of a facility. This level of

access requires individuals to recognize hazards, comply with safety protocols, understand emergency procedures, and make appropriate safety-related decisions without direct assistance. However, traditional visitor orientation programs frequently rely on lengthy information sessions that expose learners to excessive amounts of information within a short period. Such approaches often result in cognitive overload, poor knowledge retention, and reduced behavioral compliance, thereby limiting their effectiveness in high-risk environments (Albert and Hallowell, 2022; HR Dive, 2023).

Contemporary educational and safety literature suggests that adult learners benefit most from training approaches that are practical, concise, task-oriented, and immediately relevant to their operational responsibilities. Malcolm Knowles' theory of andragogy emphasizes the importance of self-directed learning and practical applicability, while emerging evidence supports the use of microlearning techniques to improve knowledge retention and reduce cognitive burden (Knowles et al., 2020; RSIS International, 2025). Furthermore, advances in digital technology have enabled organizations to integrate safety training into Visitor Management Systems (VMS), creating automated mechanisms that verify training completion before granting physical access to facilities (Occupational Health and Safety Magazine, 2024). Such systems transform administrative safety requirements into enforceable engineering controls capable of enhancing compliance and accountability.

The theoretical foundation for effective visitor safety management is further supported by established models of

accident causation and human behavior. The Swiss Cheese Model highlights the importance of multiple layers of defense in preventing accidents (Reason, 2000), while Human Performance principles emphasize that errors are predictable consequences of system conditions rather than solely individual failures (International Association of Oil and Gas Producers, 2023). Situational Awareness Theory underscores the necessity of enabling individuals to perceive, comprehend, and respond appropriately to environmental hazards (Endsley, 2023). Similarly, Safety Culture Theory advocates the integration of all personnel, including visitors, into the organization's broader commitment to safety excellence (Industrial Safety Review, 2024). Collectively, these frameworks provide a robust foundation for designing visitor training interventions that address both technical hazards and behavioral risks.

Against this backdrop, the Cenovus Lima Refinery identified a critical need to strengthen safety preparedness among unescorted visitors who are authorized to access designated non-process areas independently. Although physical access controls were already in place, management recognized that access authorization alone does not guarantee adequate hazard awareness, emergency readiness, or compliance with safety expectations. Therefore, a structured and evidence-based visitor safety training framework was required to bridge this gap and enhance overall site safety performance.

Accordingly, this study aimed to develop and implement a comprehensive safety training framework for unescorted visitors at the Cenovus Lima Refinery. The framework integrates principles of occupational safety management, adult

learning theory, microlearning, situational awareness, human performance, and digital visitor management technologies to improve hazard recognition, strengthen behavioral compliance, and support a sustainable zero-harm safety culture. By addressing the unique vulnerabilities of transient populations, the study contributes to the growing body of knowledge on visitor safety management and provides a practical model that can be adapted across petroleum refining and other high-hazard industrial sectors.

### **Study Area**

The study was conducted at the Cenovus Lima Refinery, located in Lima, Allen County, Ohio, United States, at approximately 40°44'13"N, 84°06'23"W (40.7369° N, 84.1064° W). The refinery occupies approximately 430 acres (174 ha) and is one of the major petroleum refining facilities in the U.S. Midwest, with a processing capacity of about

183,000 barrels of crude oil per day. The facility produces transportation fuels, asphalt, petrochemical feedstocks, and other refined petroleum products through complex industrial processes involving hazardous chemicals, high-pressure systems, mechanical equipment, storage facilities, and an extensive internal transportation network. Figure 1 illustrates the geographical location of the Cenovus Lima Refinery within Lima, Allen County, Ohio, USA, showing its position in the Midwestern United States. The map provides the refinery's geographic coordinates, administrative location, north arrow, and scale, thereby establishing the spatial context of the study area and supporting the identification of the facility where the evidence-based visitor safety training framework was developed and implemented.

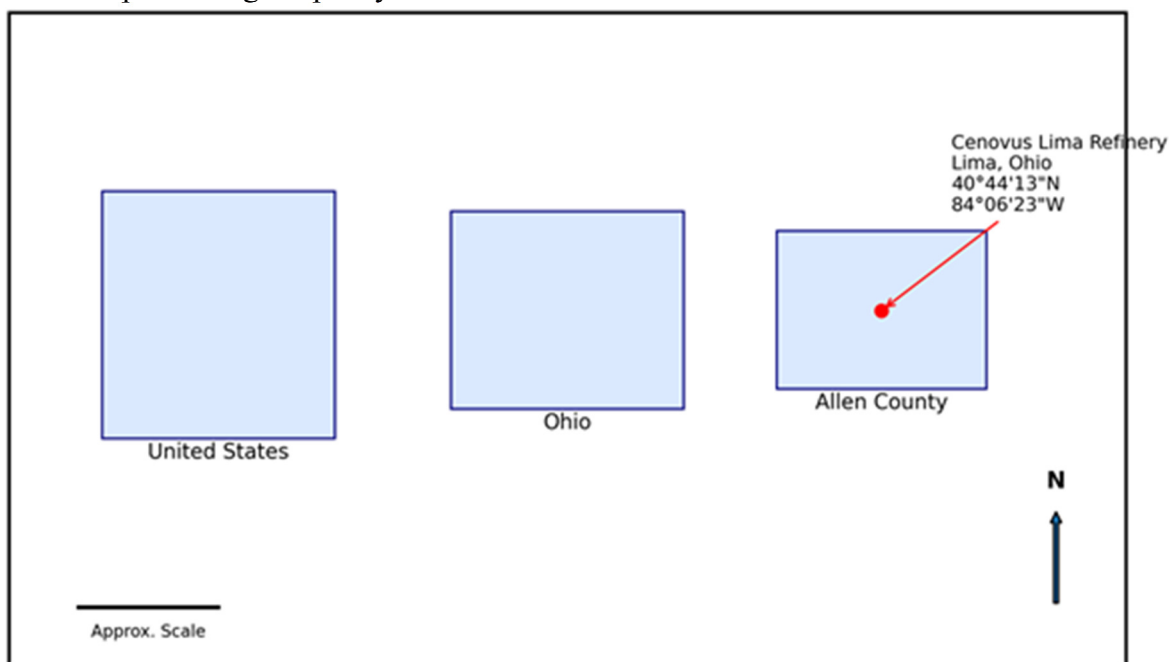


Figure 1: Location map of the Cenovus Lima Refinery, Lima, Allen County, Ohio, United States, showing the geographical location of the study area (40°44'13"N, 84°06'23"W) and its administrative setting.

## **Methodology**

### **Research Design**

This study adopted a framework-development research design to develop and implement an evidence-based safety training framework for unescorted visitors accessing designated non-process areas at the Cenovus Lima Refinery. Framework-development studies are particularly appropriate for addressing practical occupational safety challenges where the objective is to design, integrate, and evaluate systematic interventions based on existing theoretical, regulatory, and operational evidence (Nilsen, 2020; Adikwu *et al.*, 2024). The study integrated principles of occupational health and safety management, human performance, adult learning theory, and digital access-control technologies to establish a structured visitor safety management system.

The research design was informed by contemporary safety management approaches that emphasize proactive risk identification, hazard prevention, and organizational resilience rather than reactive accident investigation (Hollnagel, 2022; Gultom and Erislan, 2025). By focusing on hazard awareness, behavioral compliance, and emergency preparedness, the framework sought to improve safety performance among transient populations operating within high-risk industrial environments.

### **Framework Development Process**

The visitor safety training framework was developed using a systematic five-phase process to ensure regulatory compliance, operational relevance, and educational effectiveness, consistent with recommended approaches for occupational safety interventions and safety management systems (International Labour Organization [ILO], 2024;

Occupational Safety and Health Administration [OSHA], 2024). The framework development comprised the following phases:

#### **Phase 1: Visitor Categorization and Needs Assessment**

- ❖ Classification of visitors according to access level and risk exposure.
- ❖ Identification of safety training needs for limited-access (unescorted) visitors.

#### **Phase 2: Hazard Identification and Risk Assessment**

- ❖ Identification of hazards associated with visitor movement within designated non-process areas.
- ❖ Assessment of risks related to vehicle–pedestrian interaction, slips and falls, maintenance activities, electrical hazards, emergency situations, and security vulnerabilities.

#### **Phase 3: Curriculum Design and Development**

Development of a risk-based, microlearning safety curriculum.

- ❖ Design of five instructional modules covering site orientation, behavioral safety, personal protective equipment, emergency preparedness, and security/access-control requirements.

#### **Phase 4: Technology Integration and Training Delivery**

- ❖ Integration of the training programme into the Visitor Management System (VMS).
- ❖ Deployment of digital training, competency assessment, electronic verification, badge authorization, and visitor accountability functions.

#### **Phase 5: Compliance Monitoring and Evaluation**

- ❖ Assessment of visitor competency through mandatory evaluations.
- ❖ Monitoring of behavioral compliance, host verification, visitor audits, and

refresher training to sustain safety awareness and regulatory compliance. This five-phase process provided a structured and evidence-based approach for developing and implementing the visitor safety training framework.

#### ***Theoretical Foundation of the Framework***

The framework was underpinned by several complementary theoretical perspectives. The Swiss Cheese Model of accident causation provided the conceptual basis for establishing multiple defensive layers against visitor-related incidents (Reason, 2000). Human Performance principles guided the design of behavioral controls by recognizing that errors are predictable outcomes of system conditions and organizational influences rather than solely individual failures (IOGP, 2023).

Situational Awareness Theory informed the hazard-recognition components of the curriculum by emphasizing the ability to perceive, comprehend, and project environmental conditions (Endsley, 2023). Safety Culture Theory supported the integration of visitors into the refinery's broader commitment to safety excellence and organizational learning (Industrial Safety Review, 2024). Finally, andragogy and microlearning principles informed instructional design to maximize engagement, comprehension, and long-term retention among adult learners (Knowles *et al.*, 2020; Hug, 2021). Through the integration of these theoretical perspectives with regulatory requirements and digital management technologies, the framework provides a comprehensive and scalable approach to visitor safety management in high-hazard industrial environments.

## **Results and Discussion**

### ***Development of the Evidence-Based Visitor Safety Training Framework***

The primary outcome of this study was the successful development of a comprehensive and evidence-based safety training framework specifically designed for unescorted visitors operating within non-process areas of the Cenovus Lima Refinery. The framework was developed through a systematic process involving visitor categorization, hazard assessment, curriculum design, technology integration, and compliance monitoring. The resulting framework addresses a critical gap in industrial safety management by extending structured safety controls beyond permanent employees to transient populations, including contractors, vendors, consultants, auditors, and business partners.

Unlike conventional visitor orientation programs that focus primarily on administrative compliance, the proposed framework integrates hazard awareness, behavioral safety, emergency preparedness, and digital access-control mechanisms into a unified system. The framework therefore represents a transition from passive information dissemination toward an active risk-management approach that strengthens visitor competence while enhancing organizational control over site access and safety compliance.

### ***Visitor Risk Classification and Training Requirements***

A key outcome of the framework-development process was the establishment of a risk-based visitor classification system. Three distinct visitor categories were identified based on access privileges, exposure potential, and supervision requirements (Table 1). The

classification system allows safety resources to be allocated proportionally to visitor risk exposure. Escorted visitors rely primarily on host supervision as a safety barrier and therefore require only basic orientation. Conference-center visitors face limited exposure to operational hazards and require only emergency preparedness information. In contrast, limited-access visitors operate independently and therefore require a comprehensive understanding of site hazards, behavioral expectations, emergency procedures, and security

requirements. This risk-based categorization aligns with contemporary safety-management principles emphasizing proportional risk control and targeted intervention. The findings suggest that a standardized training approach for all visitors may be inefficient because it fails to account for varying levels of hazard exposure and operational responsibility. By tailoring training requirements to visitor risk profiles, the framework improves both training relevance and operational efficiency.

Table 1. Visitor Classification and Training Requirements

| Visitor Category           | Access Level                                             | Training Requirement          |
|----------------------------|----------------------------------------------------------|-------------------------------|
| Escorted Visitors          | Under continuous supervision                             | Minimal orientation           |
| Conference Center Visitors | Restricted to conference facilities                      | Basic emergency briefing      |
| Limited Access Visitors    | Independent movement within designated non-process areas | Comprehensive safety training |

Source: Authors' development based on Cenovus Lima Refinery visitor management procedures and safety protocols (Cenovus Energy, 2025).

### ***Hazard Awareness Enhancement***

The hazard identification phase revealed that although unescorted visitors are restricted to non-process areas, they remain exposed to numerous site-specific hazards that could adversely affect their safety. Previous studies have shown that transient personnel, including visitors and contractors, often experience elevated risk levels due to unfamiliarity with workplace environments, site layouts, hazard controls, and emergency procedures (Everant, 2024; OSHA, 2024). Consequently, hazard-awareness training emerged as one of the most critical components of the framework.

The training modules focused on six major hazard categories: (1) transitional-zone hazards, (2) vehicular traffic risks, (3) construction and maintenance

activities, (4) electrical hazards, (5) emergency alarm systems, and (6) evacuation and emergency response procedures. These hazard categories are consistent with occupational risk factors commonly identified in petroleum refining, chemical processing, and other high-hazard industrial sectors (American Petroleum Institute [API], 2021; International Labour Organization [ILO], 2024).

The findings indicate that many of these hazards are often overlooked because they occur outside operational process units. However, hazard assessments demonstrated that transitional zones connecting administrative buildings, parking areas, and meeting facilities may expose visitors to moving vehicles, temporary work activities,

overhead maintenance operations, and emergency incidents. Previous research has emphasized that pedestrian-vehicle interactions, maintenance activities, and temporary work zones constitute significant contributors to workplace injuries in industrial environments, particularly among personnel unfamiliar with site operations (National Safety Council, 2024; OSHA, 2024). Furthermore, facility-siting studies have demonstrated that non-process areas may still be vulnerable to secondary impacts arising from process incidents, including toxic releases, fires, and explosion overpressure effects (API, 2021; BakerRisk, 2024).

Particularly noteworthy was the inclusion of emergency alarm recognition and evacuation procedures. Unlike permanent employees who are continuously exposed to safety communications and emergency drills, visitors frequently lack familiarity with site-specific alarm systems and emergency response protocols (Occupational Health & Safety Magazine, 2024). The framework therefore emphasizes rapid hazard recognition and situational awareness, enabling visitors to identify hazards, interpret warning signals, and respond appropriately during emergencies. Research in emergency management consistently demonstrates that timely recognition of warning cues and familiarity with evacuation procedures significantly improve emergency response outcomes and reduce confusion during crisis situations (Federal Emergency Management Agency [FEMA], 2024; ILO, 2024).

The findings support previous research suggesting that situational awareness is a critical determinant of safety performance among inexperienced

personnel. According to Endsley (2023), situational awareness encompasses three cognitive levels: perception of environmental elements, comprehension of their significance, and projection of future conditions. Deficiencies in any of these dimensions increase the likelihood of unsafe actions and delayed responses during hazardous events. By enhancing perception, comprehension, and decision-making capabilities, the framework addresses one of the primary contributors to visitor vulnerability in industrial environments. Similar findings have been reported in studies of contractor safety and human performance, which emphasize that improved situational awareness strengthens hazard recognition, reduces human error, and promotes safer behavioral responses in complex industrial settings (IOGP, 2023; Gultom and Erislan, 2025).

### ***Behavioral Compliance Controls***

Another major outcome of the study was the incorporation of behavioral safety controls into the visitor training framework. The findings revealed that many visitor-related risks are not solely technical in nature but are strongly influenced by human behavior and decision-making processes.

To address these challenges, the framework emphasized five key behavioral expectations:

- ❖ Stop Work Authority (SWA).
- ❖ Anti-tailgating practices.
- ❖ Restricted-area compliance.
- ❖ Mobile-device restrictions.
- ❖ Security awareness and reporting responsibilities.

The inclusion of Stop Work Authority is particularly significant because it extends a core element of organizational safety culture to transient populations. Traditionally, visitors may feel reluctant to

intervene when unsafe conditions are observed because they perceive themselves as outsiders with limited authority. The framework explicitly empowers visitors to report hazards and halt activities that present immediate danger, thereby fostering shared responsibility for safety performance.

Similarly, anti-tailgating protocols were incorporated to address both safety and security vulnerabilities. The findings indicate that unauthorized access through secured entry points can compromise emergency accountability systems, undermine facility security, and increase the likelihood of personnel entering hazardous areas without proper authorization. By educating visitors on the rationale behind access-control procedures, the framework seeks to improve compliance while reducing unsafe shortcuts driven by convenience or lack of awareness.

The emphasis on behavioral compliance reflects contemporary human-performance theory, which recognizes that incidents often result from predictable interactions between individuals and organizational systems rather than deliberate rule violations. Consequently, the framework was designed not only to communicate rules but also to explain the underlying safety rationale behind those rules.

#### ***Integration of Safety Training with Digital Access Control***

Perhaps the most significant finding of this study was the integration of visitor safety training with the facility's Visitor Management System (VMS). This innovation transformed visitor training from a standalone administrative activity into an enforceable component of the refinery's safety management system.

Under the developed framework, visitors are required to complete mandatory training modules, satisfy competency assessment requirements, and verify compliance with access criteria before visitor credentials can be issued. Badge activation is automatically linked to successful completion of all training requirements.

This integration represents a substantial advancement over traditional visitor orientation approaches. In many industrial facilities, visitors receive safety briefings but may still gain access regardless of whether they fully understand or retain the information provided. By contrast, the VMS ensures that training completion becomes a prerequisite for site access, thereby eliminating opportunities for procedural bypass.

The findings demonstrate that digital integration effectively converts a behavioral requirement into a practical engineering control. From a safety-management perspective, this is particularly important because engineering and system-based controls are generally more reliable than administrative controls that depend solely on human memory and voluntary compliance.

Furthermore, the VMS enhances emergency preparedness by maintaining accurate real-time records of visitor locations, access status, and accountability information. During emergency evacuations or shelter-in-place situations, this information can significantly improve incident management and personnel accountability.

### ***Implications for Safety Culture and Visitor Management***

The findings of this study have broader implications for occupational safety management within high-hazard industries. First, they demonstrate that visitor safety should be considered an integral component of organizational safety culture rather than a peripheral administrative function. The framework extends safety expectations beyond employees to encompass all individuals entering the facility, thereby reinforcing a culture of shared responsibility and risk awareness.

Second, the study highlights the value of combining educational strategies with technological controls. The integration of microlearning, competency verification, and automated access control creates multiple layers of defense against visitor-related incidents. This layered approach reflects contemporary accident-prevention theories that advocate the implementation of multiple barriers to reduce the likelihood of adverse events.

Third, the findings suggest that digital visitor management systems can serve as powerful tools for enhancing regulatory compliance, security management, emergency preparedness, and behavioral accountability. As industrial facilities increasingly adopt digital transformation initiatives, integrating safety training with access-control technologies may represent a practical and scalable strategy for reducing risk among transient populations. The developed framework provides a robust and transferable model for managing visitor safety in petroleum refineries and other high-hazard industrial environments. By combining risk-based visitor classification, targeted hazard-awareness training, behavioral safety controls, and digital enforcement

mechanisms, the framework offers a comprehensive approach capable of improving visitor preparedness, strengthening organizational safety culture, and supporting the achievement of zero-harm objectives.

### **Conclusion**

This study developed an evidence-based safety training framework for unescorted visitors at the Cenovus Lima Refinery by integrating occupational safety management principles, adult learning theory, situational awareness, human performance concepts, microlearning, and digital visitor management technologies. The framework demonstrated that visitors, despite being restricted to designated non-process areas, remain exposed to hazards including vehicular traffic, maintenance activities, electrical risks, emergency situations, and security threats. A risk-based visitor classification system, targeted hazard-awareness training, behavioral safety expectations, emergency preparedness modules, and competency verification linked to the Visitor Management System collectively provide a structured approach for improving visitor safety. Integrating training completion with badge authorization transforms visitor orientation from a routine administrative activity into an enforceable safety control that enhances accountability and regulatory compliance. Overall, the framework strengthens organizational safety culture by extending safety responsibilities beyond employees to all facility users and provides a practical, scalable model that can be adapted across petroleum refineries and other high-hazard industries to improve visitor preparedness, reduce operational risks, and support zero-harm objectives.

## Recommendations

Based on the findings, petroleum refineries and other high-hazard industries should adopt risk-based visitor management systems that tailor safety training to visitor access levels and hazard exposure. Organizations should integrate mandatory safety training with digital Visitor Management Systems so that access authorization depends on successful completion of competency assessments. Periodic refresher training should be institutionalized to reinforce hazard awareness, emergency preparedness, and behavioral compliance among returning visitors. Management should also strengthen emergency communication, visitor accountability, and host-verification procedures to improve preparedness during incidents. Finally, future studies should evaluate the effectiveness of the proposed framework using measurable indicators such as incident frequency, safety compliance, knowledge retention, emergency response performance, and visitor behavior. Further research should also explore the application of emerging technologies, including artificial intelligence, predictive analytics, and virtual reality, to enhance visitor safety training and support continuous improvement in industrial safety management

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