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# Integrating human factors into occupational accident investigation: a literature review of methodologies and their applications

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**Abstract.** Introduction: Accident investigation is essential in safety management, aiming to identify causes and prevent recurrence. Despite various methodologies, gaps remain in information collection and human factors integration. Since data collection is the foundation of investigations, deficiencies can compromise conclusions. This study reviews literature on human factors, focusing on their integration into investigation of occupational accidents. The review explores the nature of human factors and investigation methods that address cognitive, psychological, and organisational dimensions. The study also proposes an integrated investigation flow that combines these methodologies to enhance the accuracy and effectiveness of accident investigations.
Methods: A literature review was conducted using academic databases. Keywords included 'accident investigation', 'human factors', and 'occupational safety'. Inclusion criteria focused on articles, books, and reports from 1990 to 2025, covering topics of interest and safety-critical industries. Relevant literature was screened and analysed based on its contributions to the research topic. Key investigation methodologies were analysed for their strengths and limitations.
Results: The study revealed a multitude of methodologies available, each with its own set of strengths and limitations. HFACS, HEART and FMEA methods were analysed for their potential to systematically integrate human factor. While these methodologies demonstrate significant promise, their implementation remains inconsistent due to challenges related to training, organisational culture, and resource allocation.
Conclusions: This review emphasizes the importance of integrating human factors into accident investigation methodologies to enhance workplace safety. While traditional methods remain valuable for their accessibility, systemic approaches are essential for addressing complex socio-technical systems. Future efforts should prioritize investigator training and promotion of positive organisational culture to mitigate human factor challenges and improve investigative outcomes.

**Key words:** occupational accident investigation, human factors, investigation models, safety-critical industries.

## INTRODUCTION

Production industry has witnessed significant advancements in automation and technological innovation over recent decades, which have led to increased operational efficiency and a marked reduction in manual labour-intensive processes. Despite these achievements, occupational accidents remain a persistent concern, with significant impact on human resources and productivity of entities (Laske et al., 2022; Estudillo et al., 2024). Studies indicate that even in automated industries, human factors continue to play a significant role in workplace incidents, often surpassing technical failures. (Dekker, 2006; Fernández-Muñiz et al., 2017; Pačaiová et al., 2021).

Data from the Latvian State Labour Inspectorate further supports these conclusions. It reveals that unsafe human actions are a significant cause of occupational accidents. These actions include non-compliance with safety regulations, failure to use safety equipment, and working under the influence of alcohol. Although the proportion of accidents caused by these actions has declined from 33% in 2021 to 18% in 2023, it remains a critical factor in workplace safety. Deficiencies in work organisation, such as insufficient training, poor supervision, and inadequate task control, have also played a major role in workplace accidents. These deficiencies peaked at 35% in 2022. Traffic rule violations have consistently contributed to workplace accidents, accounting for 25% in 2023. Although less prominent, unsatisfactory workplace conditions, such as the use of damaged equipment or inadequate safety tools, were cited as causes of 7% of accidents in 2023. Additionally, workplace violence emerged as a cause for the first time in 2023, accounting for 4% of accidents. The analysis of occupational accident causes from 2019 to 2023 in Latvia supports the conclusion that human factors remain a predominant cause of workplace incidents (Latvian State Labour Inspectorate, 2024).

Occupational accidents were once viewed as a linear sequence of events. Today, they are recognized as complex errors resulting from interactions between human, technological, and environmental factors, emphasizing the need for effective human factors management (Dekker, 2006; Salguero-Caparros et al., 2015). However, integrating human factors into occupational accident investigations remains challenging due to limited expertise, inconsistent methodologies, and insufficient training (Burban, 2016). As emphasised by Randle, human factors play a fundamental role in process safety management within a system, which includes the following elements: people, tasks, equipment and interfaces, environment, organisations, in which they work, and location in the world (Randle, 2021).

This challenge is compounded by the lack of a unified definition or understanding of what constitutes 'human factors'. Researchers and practitioners often interpret human factors differently, depending on their disciplinary backgrounds or the specific contexts in which they operate. The aim of this study is to explore integration of human factors into occupational accident investigations and answer following research questions:

- How have definitions and concepts of human factors evolved, and what is their relevance to occupational accident investigations today?
- How are human factors integrated into occupational safety investigations?
- What investigation methods are effective in identifying human factor in occupational accident investigations?

## METHODS

This study employed a systematic literature review approach to identify and analyse relevant research on integrating human factors into occupational accident investigations. Scopus database was queried to search for sources written in English and published between 1995 and 2025. Keywords used in the search strategy included combinations of terms 'accident investigation', 'human factors', and 'occupational safety'. Boolean operator (AND) was employed to refine the search queries.

The inclusion criteria were:

- articles, books, and reports published between 1995 and 2025;
- literature focusing on safety-critical manufacturing industries;
- publications in English language;
- Open access sources.

Exclusion criteria included studies unrelated to occupational accidents, focused solely on technical or engineering failures without considering human factors. The search initially identified 144 potentially relevant studies. Studies, that did not meet the inclusion criteria, were excluded. After screening for relevance, 78 studies were selected for analysis.

Among the wide range of investigation models identified, three methodologies - Human Factors Analysis and Classification System (HFACS), Human Error Assessment and Reduction Technique (HEART), and Failure Mode and Effects Analysis (FMEA) - emerged as particularly prominent in terms of relevance, theoretical grounding, and practical application to occupational safety contexts. These three frameworks were thus selected for focused analysis, evaluating their strengths, limitations, and application to human factors integration in occupational accident investigations.

The collected information was analysed to address the research questions outlined in this study. Specifically, the data were categorized into three primary themes: (1) human factors within occupational environment setting, (2) parameters employed to evaluate human factors, and (3) human factors in accident investigation.

By organizing the review into these topics, the analysis was aimed to explore current methodologies and propose a flow that improves accident investigation.

## RESULTS

### Human Factors within occupational environment setting

Human factors refer to psychological, cognitive, physical, and organisational elements that influence human performance in workplace settings (Kroemer et al., 2010; Reyes et al., 2015). These factors shape how individuals interact with tasks, equipment, and their working environment, impacting safety outcomes. In accident investigations, human factors provide a crucial perspective for understanding not only immediate causes but also underlying organisational, cognitive, and behavioural issues that contribute to incidents (Dekker, 2006; Hollnagel, 2014).

Human factors can be categorized into three categories. Psychological factors: emotions, attitudes, and motivations that influence behaviour and decision-making (Gervasi et al., 2022). Cognitive factors: mental workload, situational awareness, and information processing that impact task performance (Endsley, 1997; Nicoletti & Padovano, 2019). Organisational factors: leadership, training quality, communication, and safety culture that shape workplace environments (Hale et al., 2015; Randle, 2021).

The concept of human factors has evolved significantly over time. Early definitions defined human factors as the study of human interactions with machines and systems, emphasizing the need to adapt equipment to human capabilities rather than forcing individuals to adjust to poorly designed tools (Chapanis et al., 1949). Fitts (1951) introduced 'man-machine system' concept, highlighting the importance of interface design in reducing errors. This concept was later modified by Singleton to include cognitive psychology, emphasizing decision-making and problem-solving as critical components of human-machine interaction (Singleton, 1967).

A significant shift in human factors theory occurred with the introduction of systemic approaches. Senders & Moray (1977) defined human factors as a discipline aimed at improving system design to accommodate human strengths and compensate for weaknesses, highlighting the importance of creating environments that proactively prevent human errors. Human-centred design concept emerged, emphasizing usability and user experience as key components of human factors. This approach encouraged system designers to focus on human capabilities and limitations, ensuring that systems are tailored to fit human needs rather than forcing users to adapt to poorly designed environments (Norman, 1986). Reason (1990) further advanced this systemic perspective by introducing the Swiss Cheese Model, which conceptualizes human error as a symptom of deeper organisational issues. This model illustrates how multiple layers of defence (such as supervision, training, or regulations) may have weaknesses, which, when aligned, create conditions for an accident to occur. This model remains a cornerstone in understanding human error and is widely applied across industries (Perneger, 2005; Larouzée, 2017; Larouzee & Le Coze, 2020).

Contemporary definitions recognize the role of psychological and organisational aspects. This view has encouraged a shift away from focusing solely on individual errors to recognizing the systemic factors that shape employee behaviour. Hollnagel (2014) advocates for understanding how successful human performance is maintained, emphasising proactive strategies that identify and strengthen conditions that promote safe work practices. Whereas Randle (2021) points that human factors include not only individual performance but also interactions with tasks, equipment, work environment, and organisational structures. The modern understanding of ergonomics was significantly shaped by the International Ergonomics Association (IEA) under the presidency of Ian Noy. In 2000, the IEA formally adopted a definition that defined ergonomics as both a scientific discipline and practical profession, acknowledging its interdisciplinary nature and application across diverse sectors. Noy (2018) highlighted that this definition was crucial in uniting conflicting perspectives on whether ergonomics should be regarded as an academic discipline or a practical field. This definition remains one of the most important in modern safety research (Noy &William duPont IV, 2018).

Recent research by de Nobile et al. (2024) explored human factors in human-robot collaboration, addressing psychological, cognitive, and physical dimensions, emphasising the importance of interdisciplinary approaches to enhance productivity and safety in industrial settings.

As noted by Roja & Kaļķis (2020), term 'human factors' is often used to describe the ability of individuals to collaborate with one another, interact with workplace equipment and tools, and engage with management systems while considering workplace culture. The modern understanding of human factors has broadened significantly, involving not only ergonomic and physical aspects but also distinguishes between psychological, cognitive and physical human factors. Human factors refer to psychological, cognitive, physical, and organisational elements that influence human performance in workplace settings (Reyes et al., 2015). These factors shape how individuals interact with tasks, equipment, and their working environment, impacting safety outcomes. In accident investigations, human factors provide a crucial perspective for understanding not only immediate causes but also underlying organisational, cognitive, and behavioural issues that contribute to incidents (Dekker, 2006; Ferry, 2014; Hollnagel, 2014).

Human factors encompass psychological, cognitive, physical, and organisational elements that influence workplace safety (Kroemer et al., 2010; Reyes et al., 2015). While psychological and cognitive aspects are closely related, this review intentionally separates them to reflect distinct influences - psychological factors such as emotions and motivation, and cognitive factors such as mental workload and information processing (Hollnagel, 2014; Nicoletti & Padovano, 2019; Sætren et al., 2024). Although the physical domain of ergonomics is widely acknowledged, particularly by the IEA (2000), this review focuses on psychological, cognitive, and organisational dimensions due to their direct relevance to behavioural and systemic causes in accident investigations. Therefore, according to modern understanding, human factors can be categorized into three key dimensions (Table 1).

Human factors are central to the effective functioning of work systems, serving as the interface between employees, technology, and organisational structures, but variability of definitions and their understanding pose challenges for safety management (Hale et al., 2015). Despite growing recognition of human factors in safety-critical industries, traditional accident investigation methodologies still tend to prioritize technical failures over human and organisational errors (Dekker, 2006; Dien et al., 2012; Read, et al., 2021). Many investigations focus on immediate, tangible causes, such as mechanical malfunctions, rather than the underlying cognitive and organisational factors that may have contributed to the event.

A review of accident reports within industrial settings revealed that investigators often struggle to differentiate between active human errors and latent organisational conditions. For instance, in workplace incidents involving procedural violations, reports frequently attribute the event to 'worker negligence' without examining whether poor safety culture, inadequate training, or excessive workload were contributing factors (Stemn et al., 2019). This indicates a need for better integration of systemic human factors models.

**Table 1.** Key Dimensions and Elements of Human Factors in Occupational Safety

| Human factor dimension | Key element | Description |
|---|---|---|
| Psychological human factors | Emotions, attitudes | Frustration, anxiety, or overconfidence can impair judgment and increase the risk of incidents (Gervasi et al., 2022) |
| | Motivations behaviour | Employee motivation levels affect risk-taking behaviours, compliance with safety procedures, and task performance (Reyes et al., 2015) |
| | Awareness | Ensures employees recognize and respond to potential hazards, particularly critical in environments requiring rapid decision-making, where distractions and mental overload may compromise safety (Endsley, 1997; Nicoletti & Padovano, 2019; He et al., 2021), enhancing awareness through training and real-time feedback mechanisms can significantly reduce the likelihood of incidents (Naderpour et al., 2015) |
| | Trust | Important factor in team dynamics and use of safety systems. Employees who lack trust in their peers, supervisors, or organisational processes may hesitate to report risks, ultimately increasing the potential for errors (Arkin et al., 2012; Judeh, 2016) |
| Cognitive factors | Mental workload | Excessive workload can reduce focus, impair memory, and limit the ability to identify and respond to hazards effectively (Carayon, 2006) |
| | Information processing | Is critical in environments where complex decisions must be made quickly (Nicoletti & Padovano, 2019). |
| | Stress, fatigue | Can impair judgment, reduce attention, and increase error likelihood, especially in demanding or high-risk environments (Sneddon et al., 2013). |
| Organisational factors | Leadership, supervision | Effectiveness has significant influence on safety culture, encouraging compliance with procedures, and ensuring employees feel supported (Randle, 2021). |
| | Training, communication | Shape workplace environments (Randle, 2021; Hale et al., 2015) |
| | Workplace culture | If positive encourages employees to report risks, engage in safe practices, and collaborate effectively to improve workplace safety (Hale et al., 2015). |

### Integration of human factors into occupational safety investigations

Prior to integrating human factors into occupational accident investigations, it is essential to establish clear definitions of both ‘accident’ and ‘occupational safety’. Early definitions, such as Heinrich’s (1936), described accidents as ‘unplanned and uncontrolled events involving an object, person, or reaction that results in or has the potential to result in injury’. However, modern interpretations have challenged this definition, arguing that many accidents are foreseeable and preventable with adequate safety measures and systems (Hollnagel, 2004; Dekker et al., 2011).

Occupational safety refers to the measures and regulations implemented to ensure the well-being and protection of workers in their workplace. It encompasses a wide range of topics, all aimed at promoting health and well-being in the workplace. The goal of occupational safety to foster a safe and healthy work environment, which also protects co-workers, family members, employers, customers, and others who might be affected by the workplace environment (Kiersma, 2014). Understanding these definitions is important for effective integration of human factors into occupational accident investigations, as it allows for a comprehensive approach that considers both individual behaviors and systemic influences on workplace safety.

To incorporate human factors effectively into occupational accident investigations, researchers advocate for frameworks that encompass cognitive, psychological, and organisational dimensions. For instance, stress, fatigue, and mental workload are increasingly recognized as significant contributors to occupational accidents (Dekker, 2002; Dekker et al., 2011). Stress-induced errors frequently stem from inadequate safety climates and lead to poor situational awareness, delayed responses, and decision-making lapses (Moura et al., 2016). Similarly, Liao et al. (2021) demonstrated that excessive cognitive demands impair workers' ability to respond effectively to dynamic work environments, emphasising the need for cognitive workload management in safety investigations.

Human Factors Analysis and Classification System (HFACS) has emerged as one of the widely used frameworks in accident investigations, particularly for its ability to systematically identify and categorise human errors. Initially developed for aviation safety (Materna et al., 2023), HFACS has later been adapted for use in occupational safety to determine the root causes of workplace accidents (Omole & Walker, 2015; Ergai et al., 2016; Hulme et al., 2020). Numerous studies have demonstrated how HFACS can be applied in high-risk industries (Omole & Walker, 2015; Baldissone et al., 2019; Guo et al., 2023; Maternová & Materna, 2023; Wang et al., 2025). HFACS is structured according to four pillars: organisational influences, unsafe supervision, preconditions for unsafe acts, and unsafe acts themselves, allowing for a multi-layered analysis of human and systemic factors contributing to accidents (Guo et al., 2023; Wang et al., 2025). Research by Leveson et al. (2009) investigated how HFACS helps to identify latent conditions that can lead to unsafe actions. Moreover, HFACS could serve to provide input for accident prevention strategies (Wang et al., 2025), Comprehensive analysis of occupational accidents using HFACS, found that poor communication, inadequate training, and fatigue were among the most recurrent preconditions for unsafe acts (Baldissone et al., 2019). Investigation process conducted by applying HFACS method can be illustrated as follows (Fig. 1).

Another applicable method for integrating human factors into occupational accident investigation is Human Error Assessment and Reduction Technique (HEART) which is quantitative approach for evaluating the likelihood of human errors and their potential impact within complex systems. Its application in occupational accident investigations helps to quantify human error probabilities and provides a framework for understanding how these errors influence organisational safety culture and employee behaviour (Aliabadi et al., 2024; Musavi, 2024). HEART operates by assigning error probabilities to specific tasks based on influencing factors known as Error Producing Conditions (EPCs), such as stress, complexity, and lack of training (Musavi, 2024). By categorising tasks and their associated risks, HEART provides investigators with a structured methodology to identify weaknesses in work systems that may contribute to accidents (Kandemir & Celik, 2021). Investigation process conducted by applying HEART method can be illustrated as follows (Fig. 2).

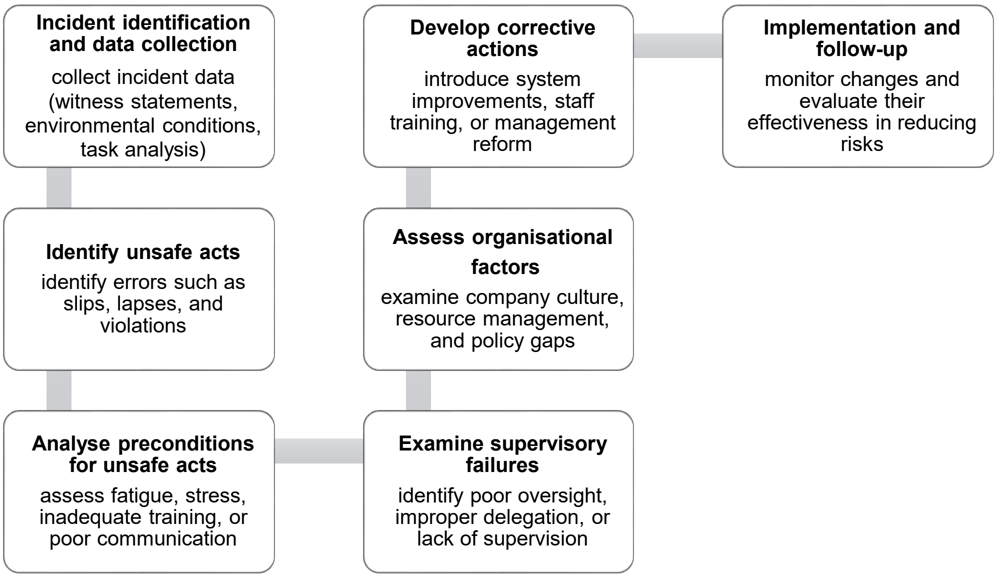


**Figure 1.** HFACS investigation process flowchart.

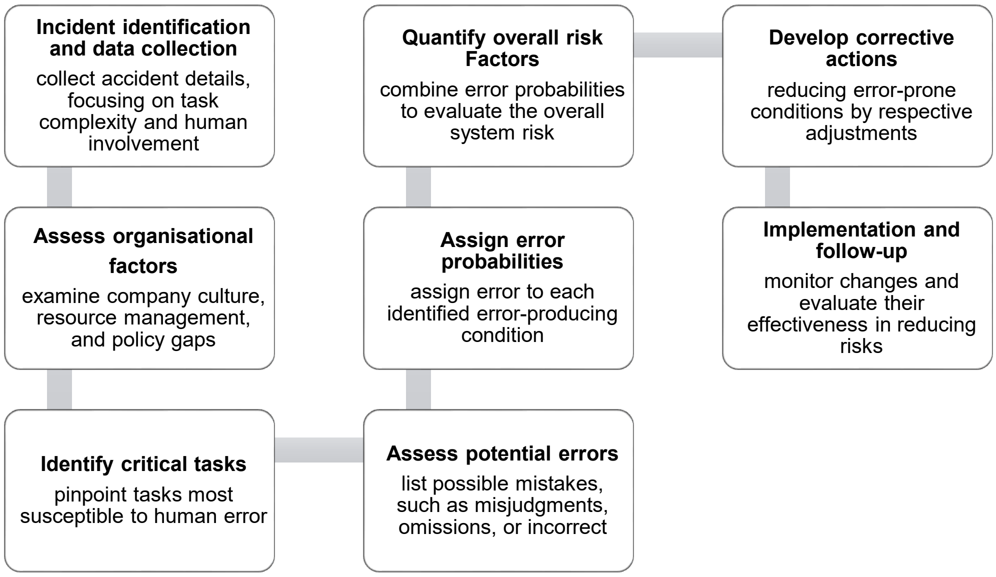


**Figure 2.** HEART investigation process flowchart.

Another method is Failure Mode and Effects Analysis (FMEA) which is structured, systematic methodology widely utilized to evaluate potential failure modes within systems and processes, analyse their causes and effects, and prioritise corrective actions to mitigate risks. In the context of occupational accident investigation, FMEA provides framework to identify error types and their impacts on investigation reports, it points human factors that contribute to deficiencies in accident analysis and documentation (Stamatis, 2014; Sutton, 2014; Chakrabarty et al., 2016; Huang et al., 2020).

Study by Liu et al. (2024) illustrates the use of FMEA in identifying latent human errors that influence accident outcomes. It was revealed that insufficient communication and procedural violations significantly affect the accuracy of investigation reports. By dissecting accident reports using FMEA, researchers can categorize human factors into several dimensions, including cognitive errors, procedural lapses, and organisational deficiencies. Huang et al. (2020) found that incorporating human factors into FMEA facilitated the identification of errors in decision-making processes during high-stress situations, a common cause of incomplete or biased accident investigations.

Additionally, FMEA, being a highly variable method, can be utilised in various industrial contexts. It was demonstrated that the method could uncover patterns of errors specific to industries such as construction and manufacturing, where accidents are frequently attributed to misjudgements or non-compliance with safety standards Liu et al. (2024). Another significant advantages of FMEA in accident investigations is its potential to improve the quality of reports by addressing gaps in data collection and analysis. Researches showed that integrating FMEA into post-accident investigations led to more detailed root cause analyses, reducing ambiguity in identifying contributing factors (Huang et al., 2020; Liu et al., 2024). Investigation process conducted by applying FMEA method can be illustrated as follows (Fig. 3).

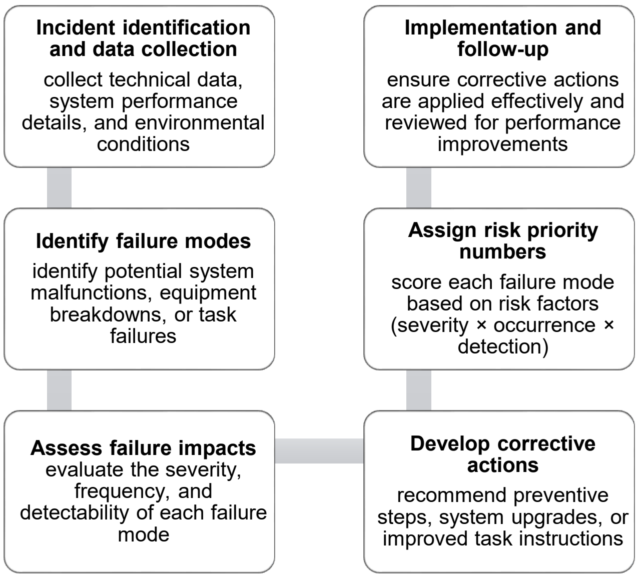


**Figure 3.** FMEA investigation process flowchart.

Each method follows a structured process that begins with gathering evidence and concludes with the implementation of corrective actions. While HFACS, HEART, and FMEA each provide distinct approaches to analysing human factors, they share a common objective: identifying key factors that contribute to incidents and ensuring effective corrective actions are developed to prevent recurrence.

Based on the analysis of methodologies discussed in the reviewed studies, the author has developed a table (Table 2) that presents a comparative overview of these methodologies and aims to provide a guide selecting the most suitable approach for specific investigation needs.

**Table 2.** Comparison of methodologies for integrating human factors into occupational safety investigations

| Method | Purpose | Strengths | Limitations | Key findings |
|---|---|---|---|---|
| HFACS | Systematic identification and classification of human errors | Identifying latent conditions and systemic issues applicable across industries, including high-risk | Requires detailed investigator training; may overlook environmental and cultural factors | Identifies latent and active errors for safety improvements |
| HEART | Quantitative assessment of human error probabilities and impacts | Useful for complex systems with multiple error sources | Relies heavily on accurate data collection subject to evaluator bias | Highlights high-risk tasks and error-prone conditions for targeted interventions |
| FMEA | Analysis of failure modes, their causes, and effects. | Flexible and applicable across diverse industries; focuses on proactive error identification | Resource-intensive require experienced teams for effective use | Identifies error types and improves the quality of accident investigation reports |

Studies have shown that integrating HEART into occupational accident investigations can significantly enhance the identification of root causes and provide a more comprehensive understanding of how human and organisational factors interact (Ginting & Tambunan, 2016; Williams & Bell, 2016). Moreover, HEART can be integrated with other methodologies like HFACS (Human Factors Analysis and Classification System) to provide a more holistic view of accident causation (Aliabadi, 2021; Kandemir & Celik, 2021; Kang et al., 2021; Octaviani & Arifin, 2024).

Integrating these methodologies can significantly enhance the identification of root causes in occupational accident investigations. Each method offers unique perspectives: HEART focuses on quantifying human error probabilities, HFACS provides a framework for analysing human and organisational factors, and FMEA systematically identifies potential failure modes and their impacts. When used jointly, these methods complement each other, offering a more comprehensive understanding of accident causation (Liou et al., 2022; Meng & Lu, 2022; Gangadhari et al., 2024).

Based on the literature study, the author proposes the following structured scheme for integrating human factors into occupational accident investigations. This scheme combines key elements from HFACS, HEART, and FMEA frameworks, addressing their strengths while mitigating their limitations (Fig. 4).

[ Initial Response ] → [ Data Collection ] → [ Preliminary Analysis ]
↓
[ HFACS Analysis ] → [ HEART Analysis ] → [ FMEA Analysis ]
↓
[ Root Cause Analysis ]
↓
[ Development of Corrective Actions ] → [ Implementation ]
↓
[ Follow-up and Monitoring ]
↓
[ Knowledge Sharing and Training ]

**Figure 4.** Integrated Process Flow for Occupational Accident Investigation Incorporating Human Factors Methodologies.

## DISCUSSION

The findings of this review highlight the complex nature and role of human factors in both the occurrence and prevention of occupational accidents. While traditional investigation methods have long emphasized technical failures, this study examined the importance of adopting approach that considers cognitive, psychological, and organisational dimensions. Human factors are complex, combining psychological, cognitive, and organisational influences that interact in dynamic ways. As research has demonstrated, human behaviour is rarely the result of a single cause. This complexity requires investigation to extend beyond technical causes and explore deeper systemic issues.

The review discovered that systemic methods can be effective in capturing the complexity of human factors, and combination of those can enhance investigation outcomes. Despite their potential, several barriers hinder the successful application of these models. The complexity of systemic approaches often requires specialized training and expertise, which may limit adoption in industries with limited resources. Furthermore, organisations that rely heavily on traditional investigative practices may be resistant to transitioning toward human factor-centred approaches

To improve the integration of human factors into occupational accident investigations, several steps could be recommended. First, developing clear, universal guidelines for applying HFACS, HEART, and FMEA can improve consistency and ensure investigators effectively identify systemic factors alongside technical causes. Second, improving investigator training is critical to building competence in identifying psychological, cognitive, and organisational contributors to workplace accidents. Third, organisations should establish structured reporting systems that capture detailed information on environmental conditions, workplace behaviour, and organisational processes. Improved data quality is crucial for identifying systemic issues and enhancing investigation accuracy. Moreover, promoting a positive safety culture within organisations can encourage employees to report risks, unsafe behaviours, and systemic concerns.

Based on the reviewed methodologies, author proposes a simplified investigation flow that combines the strengths of HFACS, HEART, and FMEA. The proposed approach begins with data collection and preliminary analysis, followed by layered application of HFACS to identify systemic and behavioural issues, HEART to assess human error probabilities, and FMEA to prioritise failure modes. These tools are used together to uncover root causes and inform corrective actions. Though this hybid approach has significant limitations such as time constraint and knowledge of the methods. Therefore, future efforts should focus on developing clear investigation guidelines, improving investigator training, and promoting comprehensive data collection practices to support successful implementation.

## CONCLUSIONS

This review has shown that the concept of human factors has evolved from a narrow focus on ergonomics to a broader, multidimensional perspective that includes psychological, cognitive, organisational, and physical elements. This shift is crucial for accurately analysing the root causes of occupational accidents. The integration of human factors into occupational safety investigations is advancing, with increasing emphasis on systemic approaches that account for both individual behaviour and organisational context. Among the reviewed methods, HFACS, HEART, and FMEA emerged as particularly effective in identifying and categorising human and organisational factors. Their structured frameworks help reveal both active and latent conditions, thereby improving the quality and impact of accident investigations.

The review highlighted several areas that would need further attention and future research to enhance the integration of human factors into occupational accident investigations which are standardization of methodologies by developing universal guidelines, investigator training and educations to enhance competency of investigators.

## REFERENCES


Aliabadi, M.M. 2021. Human error analysis in furnace start-up operation using HEART under intuitionistic fuzzy environment. *Journal of Loss Prevention in the Process Industries* **69**, 104372. doi: 10.1016/j.jlp.2020.104372

Aliabadi, M.M., Mohammadfam, I. & Khorshidikia, S. 2024. Human error identification and risk assessment in loading and unloading of petroleum products by road trucks using the SHERPA and fuzzy inference system method. *Heliyon* **10**(15), e34072. doi: 10.1016/j.heliyon.2024.e34072

Arkin, R.C., Ulam, P. & Wagner, A.R. 2012. *Moral decision making in autonomous systems: Enforcement, moral emotions, dignity, trust, and deception. Proceedings of the IEEE* **100**(3), 571–589. doi: 10.1109/JPROC.2011.2173265

Baldissone, G., Demichela, M., Comberti, L. & Murè, S. 2019. Occupational accident-precursors data collection and analysis according to Human Factors Analysis and Classification System (HFACS) taxonomy. *Data in Brief* **26**, 104479. doi: 10.1016/j.dib.2019.104479

Burban, C. 2016. *Human Factors in Air Accident Investigation: A Training Needs Analysis.* PhD Thesis, Cranfield University, School of Aerospace, Transport and Manufacturing, Cranfield, UK, 252 pp.

Carayon, P. 2006. Human factors of complex sociotechnical systems. *Applied Ergonomics* **37**(4), 525–535. doi: 10.1016/j.apergo.2006.04.011

Chakrabarty, A., Mannan, S. & Cagin, T. 2016. Process safety. In Chakrabarty, A., Mannan, S. & Cagin, T. (eds), *Multiscale Modeling for Process Safety Applications*. Elsevier, Amsterdam, 5–110. doi: 10.1016/B978-0-12-396975-0.00002-4

Chapanis, A., Garner, W.R. & Morgan, C.T. 1949. *Applied experimental psychology: Human factors in engineering design.* John Wiley & Sons Inc., New York, 504 pp.

De Nobile, A., Bibbo, D., Russo, M. & Conforto, S. 2024. A focus on quantitative methods to assess human factors in collaborative robotics. *International Journal of Industrial Ergonomics* **104**, 103663. doi: 10.1016/j.ergon.2024.103663

Dekker, S. 2002. Reconstructing human contributions to accidents: The new view on error and performance. *Journal of Safety Research* **33**(3), 371–385. doi: 10.1016/S0022-4375(02)00032-4

Dekker, S. 2006. *The Field Guide to Understanding Human Error.* Ashgate Publishing Company, Farnham, 276 pp.

Dekker, S., Cilliers, P. & Hofmeyr, J.-H. 2011. The complexity of failure: Implications of complexity theory for safety investigations. *Safety Science* **49**(6), 939–945. doi: 10.1016/j.ssci.2011.01.008

Dien, Y., Dechy, N. & Guillaume, E. 2012. Accident investigation: From searching direct causes to finding in-depth causes – Problem of analysis or/and of analyst? *Safety Science* **50**, 1398–1407. doi: 10.1016/j.ssci.2011.12.010

Endsley, M.R. 1997. Supporting situation awareness in aviation systems. In: *Proceedings of the 1997 IEEE International Conference on Systems, Man, and Cybernetics: Computational Cybernetics and Simulation.* IEEE, Orlando, FL, USA, pp. [page numbers if available]. doi: 10.1109/ICSMC.1997.637352

Ergai, A., Cohen, T., Sharp, J., Wiegmann, D., Gramopadhye, A. & Shappell, S. 2016. Assessment of the Human Factors Analysis and Classification System (HFACS): Intra-rater and inter-rater reliability. *Safety Science* **82**, 393–398. doi: 10.1016/j.ssci.2015.09.018

Estudillo, B., Carretero-Gómez, J.M. & Forteza, F.J. 2024. The impact of occupational accidents on economic performance: Evidence from the construction sector. *Safety Science* **174**, 106571. doi: 10.1016/j.ssci.2024.106571

Fernández-Muñiz, B., Montes-Peón, J.-M. & Vázquez-Ordás, C.-J. 2017. Leadership and work safety culture: State of the art review. *Dyna (Spain)* **92**(1), 39–42. doi: 10.6036/7942

Ferry, T.S. 2014. How to ensure a good investigation. In Charles C. Thomas (eds) *Readings in Accident Investigation: Examples of Scope, Depth, and Sources*. Springfield, IL, 13–23.

Fitts, P.M. (Ed.) 1951. *Human engineering for an effective air-navigation and traffic-control system.* National Research Council, Washington, DC, 198 pp.

Gangadhari, R.K., Rabiee, M., Khanzode, V., Murthy, S. & Tarei, P.K. 2024. From unstructured accident reports to a hybrid decision support system for occupational risk management: The consensus converging approach. *Journal of Safety Research* **89**, 91–104. doi: 10.1016/j.jsr.2024.02.006

Gervasi, R., Aliev, K., Mastrogiacomo, L. & Franceschini, F. 2022. User experience and physiological response in human-robot collaboration: A preliminary investigation. *Journal of Intelligent & Robotic Systems: Theory and Applications* **106**. doi: 10.1007/s10846-022-01744-8

Ginting, E. & Tambunan, M.M. 2016. Analysis of accidents through the approach of human error and job safety analysis (JSA). In *Proceedings of the 1st Public Health International Conference (PHICo 2016). Advances in Health Sciences Research.* doi: 10.2991/phico-16.2017.27

Guo, Z., Pang, H., Zhang, J., Zhang, J., Wang, J. & He, C. 2023. Using HFACS to understand human error in railway dispatcher performance: A study of proactive safety inspection records. *Ergonomics* **67**(1), 37–50. doi: 10.1080/00140139.2023.2287975

Hale, A., Borys, D. & Adams, M. 2015. Safety regulation: The lessons of workplace safety rule management for managing the regulatory burden. *Safety Science* **71**(Part B), 112–122. doi: 10.1016/j.ssci.2013.11.012

He, Y., Kuai, N.-S., Deng, L.-M. & He, X.-Y. 2021. A method for assessing Human Error Probability through physiological and psychological factors tests based on CREAM and its applications. *Reliability Engineering & System Safety* **215**, 107884. doi: 10.1016/j.ress.2021.107884

Heinrich, H.W. 1936. *Industrial Accident Prevention: A Scientific Approach.* McGraw-Hill, New York, 478 pp.

Hollnagel, E. 2004. *Barriers and Accident Prevention.* Routledge, London, 242 pp. doi: 10.4324/9781315261737

Hollnagel, E. 2014. *Safety-I and Safety-II: The Past and Future of Safety Management*. 1st ed. CRC Press, London, 200 pp. doi: 10.1201/9781315607511

Huang, J., You, J.-X., Liu, H.-C. & Song, M.-S. 2020. Failure mode and effect analysis improvement: A systematic literature review and future research agenda. *Reliability Engineering & System Safety* **199**, 106885. doi: 10.1016/j.ress.2020.106885

Hulme, A., Stanton, N.A. & Salmon, P.M. 2020. Accident analysis in practice: A review of Human Factors Analysis and Classification System (HFACS) applications in the peer-reviewed academic literature. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* **63**(1). doi: 10.1177/1071181319631086

International Ergonomics Association (IEA) & International Labour Organization (ILO). 2019. *Principles and Guidelines for HF/E Design and Management of Work Systems*. Joint Document by IEA and ILO.

Judeh, M. 2016. The influence of organizational trust on job performance: Mediating role of employee engagement. *International Journal of Business Research* **16**(5), 53–66. doi: 10.18374/IJBR-16-5.4

Kandemir, C. & Celik, M. 2021. Determining the error producing conditions in marine engineering maintenance and operations through HFACS-MMO. *Reliability Engineering & System Safety* **206**, 107308. doi: 10.1016/j.ress.2020.107308

Kang, Y., Yang, S. & Patterson, P. 2021. Modern cause and effect model by factors of root cause for accident prevention in small to medium-sized enterprises. *Saf. Health Work* **12**, 505–510. doi: 10.1016/j.shaw.2021.08.002

Kroemer, K., Kroemer, H.J. & Kroemer-Elbert, K.E. 2010. *Engineering Physiology: Bases of Human Factors Engineering/Ergonomics*. Springer, Berlin, Heidelberg. doi: 10.1007/978-3-642-12883-7

Kiersma, M.E. 2014. Occupational Safety and Health Administration. *In Encyclopedia of Toxicology* (3rd ed., p. 642). Elsevier. doi: 10.1016/B978-0-12-386454-3.00344-4

Larouzee, J. & Le Coze, J.-C. 2020. Good and bad reasons: The Swiss cheese model and its critics. *Safety Science* **126**, 104660. https://doi.org/10.1016/j.ssci.2020.104660

Larouzée, J. 2017. Human error and defense in depth: From the 'Clambake' to the 'Swiss Cheese'. In Ahn, J., Guarnieri, F. & Furuta, K. (eds), *Resilience: A New Paradigm of Nuclear Safety*. Springer, Cham, pp. 257–267. doi: 10.1007/978-3-319-58768-4_22

Laske, M.P., Hinson, E., Acikgoz, Y., Ludwig, T.D., Foreman, A.M. & Bergman, S.M. 2022. Do employees' work schedules put them at-risk? The role of shift scheduling and holidays in predicting near miss and incident likelihood. *Journal of Safety Research* **83**, 1–7. https://doi.org/10.1016/j.jsr.2022.07.015

Latvian State Labour Inspectorate. 2024. 2023. gada darbības pārskats. Valsts Darba inspekcija, Rīga, pp. 25–28, 2023 Activity Report

Leveson, N., Dulac, N., Marais, K. & Carroll, J.S. 2009. Moving beyond normal accidents and high reliability organizations: A systems approach to safety in complex systems. *Organization Studies* **30**(2–3), 227–249. doi: 10.1177/0170840608101478

Liao, P.-C., Sun, X. & Zhang, D. 2021. A multimodal study to measure the cognitive demands of hazard recognition in construction workplaces. *Safety Science* **133**, 105010. doi: 10.1016/j.ssci.2020.105010

Liu, P., Wu, Y., Li, Y. & Wu, X. 2024. An improved FMEA method based on the expert trust network for maritime transportation risk management. *Expert Systems with Applications* **238**, 121705. https://doi.org/10.1016/j.eswa.2023.121705

Liou, J.J.H., Liu, P.C.Y., Luo, S.-S., Lo, H.-W. & Wu, Y.-Z. 2022. A hybrid model integrating FMEA and HFACS to assess the risk of inter-city bus accidents. *Complex & Intelligent Systems* **8**(4), 2451–2470. Doi: 10.1007/s40747-022-00657-1

Materna, M., Maternová, A., Kamenická, D. & Chodelka, F. 2023. The influence of human factor on aviation accidents in Slovakia through HFACS framework: A comprehensive study. *Transportation Research Procedia* **75**, 173–182. doi: 10.1016/j.trpro.2023.12.020

Maternová, A. & Materna, M. 2023. Research of maritime accidents based on HFACS framework. *Transportation Research Procedia* **74**, 1224–1231. doi: 10.1016/j.trpro.2023.11.265
Meng, B. & Lu, N. 2022. A hybrid model integrating HFACS and BN for analyzing human factors in CFIT accidents. *Aerospace* **9**(11), 711. doi: 10.3390/aerospace9110711
Moura, R., Beer, M., Patelli, E., Lewis, J. & Knoll, F. 2016. Learning from major accidents to improve system design. Safety Science, 84, 37–45. Doi: 10.1016/j.ssci.2015.11.022
Musavi, F., Hekmatshoar, R., Fallahi, M., Moradi, A. & Yazdani-Aval, M. 2024. Identifying and preventing human error in the sugar production process: A multi-stage approach using HTA, HEC and PHEA techniques. *Heliyon* **10**(9), e29687. doi: 10.1016/j.heliyon.2024.e29687
Naderpour, M., Lu, J. & Zhang, G. 2015. A human-system interface risk assessment method based on mental models. *Safety Science* **79**, 82–99. doi: 10.1016/j.ssci.2015.07.001
Nicoletti, L. & Padovano, A. 2019. Human factors in occupational health and safety 4.0: A cross-sectional correlation study of workload, stress and outcomes of an industrial emergency response. *International Journal of Simulation and Process Modelling* **14**(2), 178–195. https://doi.org/10.1504/IJSPM.2019.099912
Norman, D.A. 1986. Cognitive engineering. In Draper, S. W. (ed.), *User centered system design.* Lawrence Erlbaum Associates, Hillsdale, NJ.
Noy, I. & duPont, W. IV. 2018. The long-term consequences of disasters: What do we know, and what we still don't. *International Review of Environmental and Resource Economics* **12**(4), 325–354. doi: 10.1561/101.00000104
Octaviani, F. & Arifin, M.D. 2024. Analysis of human error probability at shipyard using Human Error Assessment and Reduction Technique (HEART). *International Journal of Marine Engineering Innovation and Research* **9**(1), 105–113. doi: 10.12962/j25481479.v9i1.20169
Omole, H. & Walker, G. 2015. Offshore transport accident analysis using HFACS. *Procedia Manufacturing* **3**, 1264–1272. https://doi.org/10.1016/j.promfg.2015.07.270
Pačaiová, H., Tomašková, M., Balážiková, M. & Krajňák, J. 2021. Analysis of air-traffic threats. *Scientific Journal of Silesian University of Technology. Series Transport* **110**, 143–155. doi: 10.20858/sjsutst.2021.110.12
Perneger, T.V. 2005. The Swiss cheese model of safety incidents: Are there holes in the metaphor? *BMC Health Services Research* **5**, Article 71. https://doi.org/10.1186/1472-6963-5-71
Randle, I. 2021. Introduction to human factors and the human element. *Process Safety Management and Human Factors* **2021**, 9–23. doi: 10.1016/B978-0-12-818109-6.00002-2
Read, G.J.M., Shorrock, S., Walker, G.H. & Salmon, P.M. 2021. State of science: Evolving perspectives on 'human error'. *Ergonomics* **64**(9), 1091–1114. doi: 10.1080/00140139.2021.1953615
Reason, J. 1990. *Human Error.* Cambridge University Press, Cambridge, 302 pp.
Reyes, R.M., de la Riva, J., Maldonado, A., Woocay, A. & R. de la O. 2015. Association between human error and occupational accidents' contributing factors for hand injuries in the automotive manufacturing industry. *Procedia Manufacturing* **3**, 6498–6504. doi: 10.1016/j.promfg.2015.07.947
Roja, Ž. & Kaļķis, H. 2020. *Human Factors and Ergonomics at Work / Cilvēkfaktors un ergonomika darbā*. Gutenbergs druka, Rīga, 295 pp.
Sætren, G.B., Ernstsen, J., Phillips, R., Aulie, E.G. & Stenhammer, H.C. 2024. Cognitive technology development and end-user involvement in the Norwegian petroleum industry – Human factors missing or not? *Safety Science* **170**, 106337. doi: 10.1016/j.ssci.2024.106337
Salguero-Caparros, F., Suarez-Cebador, M. & Rubio-Romero, J.C. 2015. Analysis of investigation reports on occupational accidents. *Safety Science* **72**, 329–336. doi: 10.1016/j.ssci.2014.10.005
Senders, J.W. & Moray, N.P. 1991. *Human error: Cause, prediction, and reduction.* CRC Press, Boca Raton, 168 pp.

Singleton, W.T. 1967. Ergonomics in systems design. *Ergonomics* **10**(5), 541–548. doi: 10.1080/00140136708930908

Sneddon, A., Mearns, K. & Flin, R. 2013. Stress, fatigue, situation awareness and safety in offshore drilling crews. *Safety Science* **56**, 80–88. doi: 10.1016/j.ssci.2012.05.027

Stamatis, D.H. 2014. *Introduction to Risk and Failures: Tools and Methodologies.* CRC Press, Boca Raton, 274 pp. doi: 10.1201/b16855.

Stemn, E., Hassall, M.E., Cliff, D. & Bofinger, C. 2019. Incident investigators' perspectives of incident investigations conducted in the Ghanaian mining industry. *Safety Science* **112**, 173–188. doi: 10.1016/j.ssci.2018.10.026

Sutton, I. 2014. Safety and Environmental Management Systems. In Sutton, I. (eds), *Offshore Safety Management (Second Edition)*. Elsevier, Amsterdam, 139–212. doi: 10.1016/B978-0-323-26206-4.00005-8

Wang, J., Huang, X., Mai, M., Fang, S., Zhang, Q., Huang, H. & Yang, D. 2025. Enhancing maritime safety in offshore wind power engineering: A holistic approach to accident cause analysis, barrier design, and mitigation strategies - HFACS+Bowtie+C. *Ocean Engineering* **316**, 119964. doi: 10.1016/j.oceaneng.2024.119964

Williams, J.C. & Bell, J.L. 2016. Consolidation of the Error Producing Conditions used in the Human Error Assessment and Reduction Technique (HEART). *Theoretical Issues in Ergonomics Science* **17**(1), 26–76. doi: 10.1080/09617353.2015.11691047