Jurnal Kesehatan dan Keselamatan Kerja Indonesia

Volume. 1, Issue 1 November 2025
Page No: 1-14

Safety Management Systems in High-Risk Sectors: Comparative Analysis and Policy Implications

Arwan[1], Indra Afrianto[2], Muhammad Syukran[3]
Universitas Tadulako, Indonesia[1]
Universitas Muhammadiyah Palu, Indonesia[23]
Correspondent : arwan_arifin@yahoo.co.id [1]

Received : October 03, 2025
Accepted : November 05, 2025
Published : November 30, 2025

Citation: Arwan,. Afrianto, I., & Syukran, M. (2025). Safety Management Systems in High-Risk Sectors: Comparative Analysis and Policy Implications. Jurnal Kesehatan dan Keselamatan Kerja Indonesia, 1(1), 1-14.

ABSTRACT: Safety Management Systems (SMS) have emerged as essential tools for managing risk and improving operational safety across high-risk industries such as aviation, construction, oil and gas, and healthcare. This narrative review aims to evaluate how SMS are integrated and how effective they are in each sector. Using a structured literature search across Scopus, PubMed, and Google Scholar, studies were selected based on relevance, peer-review status, and sectoral applicability. The review analyzes qualitative and quantitative evidence from case studies, organizational reports, and empirical research across the targeted industries. Findings reveal that sectors with centralized operations and international regulatory oversight, such as aviation and healthcare, experience greater success in SMS implementation, particularly in incident reporting and risk mitigation. In contrast, construction and oil and gas sectors encounter significant barriers, including fragmented project structures, human error prevalence, and limited stakeholder coordination. Systemic factors such as leadership commitment, safety culture, workforce training, and technology integration critically influence the success of SMS across all sectors. The study underscores the need for policy reforms and sector-specific strategies that encourage safety innovation, adaptability, and workforce participation. Future research is recommended to explore underreported failures and apply interdisciplinary frameworks that integrate behavioral insights. Enhancing SMS across sectors is vital to creating resilient, safe, and responsive operational environments in a rapidly evolving industrial landscape.

Keywords: Safety Management Systems, Risk Mitigation, Industry Comparison, Operational Safety, Human Factors, Safety Culture, Regulatory Compliance.

INTRODUCTION

Safety Management Systems (SMS) have become essential organizational frameworks for managing operational risks, particularly in high-risk sectors such as aviation, construction, oil and gas, and healthcare. Rooted in the principles of proactive risk identification, mitigation, and continuous improvement, SMS frameworks enable organizations to foster a culture of safety

through systematic approaches to hazards and their control. According to the International Civil Aviation Organization (ICAO), an SMS is a structured method of managing safety that integrates organizational structures, responsibilities, policies, and procedures (Simsekler et al., 2019). These components work synergistically to ensure operational integrity and personnel safety by identifying hazards, evaluating associated risks, implementing preventive strategies, and continuously monitoring safety performance.

In the construction industry, the integration of technology into SMS—particularly Building Information Modeling (BIM) and the Internet of Things (IoT)—has significantly improved real-time monitoring and incident response on worksites (Xu et al., 2019; Alizadehsalehi et al., 2018). These innovations allow safety managers to identify risk hotspots and intervene proactively (Sadeghi et al., 2020). Similarly, the oil and gas industry has seen a growing reliance on advanced analytics and risk management methodologies to address complex operational risks in upstream and downstream environments (Tayab et al., 2024; Rasmuson et al., 2015). Meanwhile, the healthcare sector emphasizes risk control systems that align patient safety initiatives with clinical efficiency, embedding SMS principles into healthcare quality management (Boudreaux & Vetter, 2013).

Global adoption of SMS has increased notably over the past decade, driven by evolving regulations, enhanced public scrutiny, and technological progress. In aviation, SMS implementation is mandated by international regulatory bodies, leading to demonstrable improvements in safety metrics and incident prevention (Nabia et al., 2023; Simsekler et al., 2019). In construction, SMS principles are being integrated into project life cycles to ensure that safety considerations are addressed alongside project deliverables (Sadeghi et al., 2020). The oil and gas sector has embraced SMS as a strategic tool to balance safety and sustainability concerns, particularly in light of environmental pressures and rising operational complexity (Tayab et al., 2024). These trends reflect a larger paradigm shift toward data-informed safety cultures.

Emerging technologies further support this shift by enhancing predictive safety capabilities. Data analytics, machine learning, and digital twins are increasingly utilized to simulate risk scenarios and inform decision-making processes (Akram & Affandi, 2024; Bakar et al., 2021). Additionally, augmented reality systems allow for immersive safety training and scenario testing in real-time, improving workforce preparedness. These innovations support a more resilient and responsive SMS framework, enabling organizations to preemptively address safety challenges (Sia et al., 2024; Chen & Bria, 2022). Ultimately, SMS has evolved from a regulatory requirement to a foundational component of sustainable organizational practice.

Despite this progress, significant challenges remain in effectively integrating SMS into organizational operations. A key barrier is the lack of senior management involvement, which undermines the cultural and procedural embedding of safety principles (Markowski et al., 2021). Another obstacle is the insufficient training of personnel, which can hinder proper implementation of safety protocols and erode trust in the system (Ciavarelli, 2016). Moreover, inconsistency between different management systems can create confusion, leading to reduced SMS effectiveness (Santos et al., 2021). Resistance to change, particularly when new procedures disrupt established workflows, also presents a substantial challenge (Yunusa-Kaltungo et al., 2022).

The consequences of weak SMS implementation are far-reaching. On the safety front, poor integration results in a higher incidence of workplace accidents and hazardous events, thereby endangering employees and compromising operational reputations (Tayab et al., 2024). Economically, such incidents lead to substantial financial costs, including worker compensation, equipment damage, and regulatory fines (Sadeghi et al., 2020). Inefficient SMS practices have also been associated with elevated operational costs, reduced productivity, and inflated insurance premiums (Ciavarelli, 2016). Furthermore, frequent incidents can negatively impact employee morale and job satisfaction, ultimately leading to higher staff turnover and increased recruitment and training expenses (Rey-Merchán et al., 2023).

In light of these challenges, there is a pressing need for organizations to invest in training programs, foster a culture of safety at all organizational levels, and ensure top-down commitment. By doing so, organizations can construct safer, more efficient workplaces and realize long-term operational and financial benefits. A holistic approach that incorporates leadership engagement, continuous learning, and strategic alignment between safety and business goals is essential for effective SMS integration.

A critical gap in the existing literature is the absence of a comprehensive, cross-sectoral comparison of SMS frameworks. Much of the existing research remains siloed within specific industries, limiting the generalizability of insights across sectors (Tayab et al., 2024; Chen & Bria, 2022). For example, while SMS in aviation may include detailed reporting systems and crew resource management protocols, these practices may not translate directly to the oil and gas sector without significant adaptation (Sadeghi et al., 2020). Furthermore, cultural, technological, and structural factors vary significantly across industries, affecting the applicability and success of SMS implementations (Kruszyński & Dawidowicz, 2020).

This narrative review aims to address these gaps by offering a comprehensive analysis of SMS integration and effectiveness across multiple high-risk industries. The objective is to identify common success factors and sector-specific challenges that influence SMS outcomes. By comparing SMS frameworks and implementations, this review seeks to inform best practices and guide future policy and organizational strategies aimed at strengthening safety performance (Akram & Affandi, 2024; Herkenhoff et al., 2023). In doing so, the study also examines how different industries can learn from one another to develop more adaptable and resilient SMS infrastructures.

The review focuses on SMS implementation in four primary sectors: aviation, construction, oil and gas, and healthcare. These sectors were selected due to their high exposure to operational risks and varying maturity levels in SMS adoption. The analysis covers global case studies, with emphasis on both developed and developing regions, to ensure a balanced understanding of contextual factors. This geographical and sectoral diversity provides a richer insight into the challenges and enablers of SMS implementation worldwide.

Through synthesizing evidence from diverse industrial settings, the review endeavors to promote a deeper understanding of how SMS frameworks can be customized and scaled to different organizational contexts. The review also explores the potential of SMS to serve as a driver of

innovation, efficiency, and organizational resilience, particularly in rapidly changing environments (Hajiyeva et al., 2023). By fostering data-driven decision-making and a robust safety culture, SMS can significantly enhance not only risk mitigation but also long-term organizational performance and competitiveness (Herkenhoff et al., 2023; Zhang et al., 2024).

METHOD

This narrative review employed a structured and systematic approach to identify, select, and analyze peer-reviewed literature focusing on the integration and effectiveness of Safety Management Systems (SMS) across diverse industrial sectors. The methodological process was guided by an intention to ensure academic rigor, transparency, and replicability, thus enhancing the reliability and depth of the insights generated. This section details the processes used for literature retrieval, selection, and synthesis.

The first step involved identifying relevant academic literature from three prominent databases widely recognized in the field of safety and risk management: Scopus, PubMed, and Google Scholar. These databases were chosen due to their comprehensive coverage of peer-reviewed journals, relevance across multidisciplinary fields, and robust indexing capabilities. The time frame for the literature search was not limited to specific publication years in order to capture the evolution and trends in SMS integration over time. However, preference was given to publications from the last 10–15 years, particularly those reflecting recent advancements in technology and cross-industry safety applications.

To locate appropriate articles, a combination of carefully selected keywords and Boolean operators was employed. Keywords included “Safety Management Systems,” “SMS integration,” “safety performance,” “risk management,” “industry comparison,” “aviation safety,” “construction safety,” “oil and gas safety,” and “healthcare safety.” The Boolean operators AND, OR, and NOT were used to refine search queries. For instance, the search string "Safety Management Systems" AND "integration" AND (aviation OR construction OR healthcare OR oil and gas) was used to retrieve documents specific to SMS implementation across high-risk industries. The operator NOT was utilized to exclude unrelated engineering-focused studies, as in "Safety Management Systems" NOT "engineering" to filter out theoretical or mechanical design research irrelevant to management system integration.

All retrieved articles were imported into a citation management software to ensure accurate documentation and ease of reference. Following retrieval, each article was subjected to a two-stage screening process: title and abstract screening, followed by full-text assessment. The inclusion criteria guided this process and were established to ensure consistency and academic relevance. Articles were included if they (1) addressed the integration of SMS within a specific industrial context (aviation, construction, oil and gas, or healthcare), (2) analyzed the effectiveness, impact, or challenges of SMS implementation, and (3) were published in peer-reviewed academic journals. These criteria ensured that the selected studies offered empirical, theoretical, or review-based insights into SMS performance and alignment with safety objectives.

Conversely, exclusion criteria were applied to eliminate studies that did not contribute directly to the aims of the review. Articles were excluded if they (1) did not explicitly discuss SMS integration or effectiveness, (2) were not published in English, or (3) focused on basic science or engineering models that did not translate into practical SMS applications. Editorials, conference abstracts, and unpublished theses were also excluded to maintain a high standard of academic rigor. In cases where the relevance of a study was uncertain, consensus was sought through critical discussion among the review team members.

In terms of study design, this narrative review included a wide range of research methodologies to ensure a holistic perspective. These included qualitative case studies, quantitative analyses, mixed-method research, and systematic reviews that met the inclusion criteria. Randomized controlled trials and experimental studies were not explicitly required, given the managerial and organizational nature of SMS topics, but when available, such rigorous empirical studies were prioritized for their high evidentiary value. Many of the included studies focused on organizational assessments, employee surveys, longitudinal analyses, or comparative evaluations of SMS across sectors. This methodological diversity enriched the synthesis process and allowed the review to highlight both broad patterns and context-specific insights.

After finalizing the pool of studies, a qualitative synthesis approach was used to extract and categorize relevant information. Each article was read thoroughly and thematically coded according to predefined themes: (1) SMS integration processes, (2) effectiveness outcomes (e.g., reduction in incident rates, safety compliance), (3) challenges and barriers to implementation, and (4) industry-specific innovations or adaptations. Additional subthemes were added inductively based on emergent patterns, such as the role of digital technologies or organizational culture in SMS success.

The methodological rigor of each study was assessed informally based on criteria such as clarity of research objectives, appropriateness of methodology, transparency of results, and contribution to the literature. Although formal quality scoring systems (e.g., CASP or PRISMA) were not applied, the exclusion of non-peer-reviewed and non-English publications acted as a preliminary quality filter.

To minimize bias, efforts were made to capture literature across various global regions, allowing for both developed and developing country contexts to be reflected in the review. This geographical diversity enabled the examination of how regulatory environments, cultural attitudes towards safety, and resource availability influenced SMS integration and outcomes.

In summary, the methodology of this review prioritized relevance, academic rigor, and comprehensive coverage across multiple databases and industries. By focusing on peer-reviewed studies that explicitly address SMS integration and its outcomes, the review provides a robust foundation for analyzing current practices, identifying best approaches, and uncovering systemic gaps in the literature. This methodologically structured approach enhances the credibility of the findings and their applicability to both policy and practice in high-risk industrial environments.

RESULT AND DISCUSSION

The implementation of Safety Management Systems (SMS) across various high-risk industries—aviation, construction, oil and gas, and healthcare—demonstrates diverse outcomes shaped by contextual challenges, regulatory standards, and technological integration. This section presents the synthesis of findings across these sectors, emphasizing how SMS are adopted, what results have been observed, and what industry-specific adaptations have proven effective.

SMS in the Aviation Industry

In civil aviation and pilot training, SMS adoption has become mandatory following regulations by the International Civil Aviation Organization (ICAO), which established structured guidance requiring organizations to implement proactive safety policies. These systems encompass risk assessments, safety reporting protocols, and continuous learning environments (Toyserkani et al., 2020). For example, simulation-based training programs and scenario modeling have been embedded into the curriculum of flight academies and professional pilot certification processes to reinforce real-time decision-making and situational awareness (Zhang et al., 2024). These methods aim not only to cultivate individual competencies but also to reinforce a culture of safety throughout the operational framework.

Empirical evidence substantiates the effectiveness of SMS in reducing aviation-related incidents. Ciavarelli (2016) reported a marked reduction in fatal accident rates in airlines that embraced full-scale SMS deployment. Similarly, Simsekler et al. (2019) found that safety reporting increased significantly after implementing structured incident tracking systems, leading to improved transparency and enhanced risk communication. In another multi-airline study, Leblanc et al. (2016) demonstrated that organizations with well-integrated SMS experienced fewer disruptions and a consistent decline in minor incidents due to early intervention. These improvements are linked not only to operational safeguards but also to the development of a positive safety climate among crew members and technicians.

SMS in the Construction Industry

The construction industry faces particular challenges in SMS implementation due to the dynamic, multi-party nature of projects and frequent environmental uncertainties. Xu et al. (2019) highlighted that inconsistencies between contractors and subcontractors in applying safety protocols can hinder a unified approach to hazard control. Moreover, mobile workforces, short project cycles, and fragmented communication lines have been cited as obstacles in executing SMS consistently across sites (Chen & Bria, 2022). Compounding these issues is the resistance from workers, who often perceive safety policy changes as disruptive to workflows or unnecessary unless directly linked to incident reduction.

Nevertheless, technological interventions such as ontology-based safety knowledge systems have provided a means of mitigating these issues. Nabia et al. (2023) showed that these systems help structure safety data, facilitate access to best practices, and enable cross-role communication, especially in large-scale infrastructure projects. The Human-Organizational-Technical (HOT) approach has also proven effective in integrating worker behavior, organizational policies, and safety engineering to reduce accident rates (Sadeghi et al., 2020). A five-year observational study of six mega-projects indicated that HOT-driven SMS resulted in a measurable decline in safety

violations and increased worker compliance (Kıvrak et al., 2013), further supporting the synergy between systemic design and human factors.

SMS in the Oil and Gas Industry

The oil and gas industry benefits from the dual integration of SMS with Process Safety Management (PSM) to manage both organizational and technical risks. Tayab et al. (2024) noted that aligning SMS with PSM mechanisms led to an integrated hazard mitigation framework capable of addressing both operational breakdowns and human error. This integration enhances the detection of early warning signs, supports incident investigation, and strengthens compliance with environmental and regulatory mandates. Data analytics and real-time monitoring are central to this model, offering predictive capabilities that help prevent major industrial failures.

Studies on upstream operations demonstrated that sites utilizing combined SMS-PSM systems experienced higher operational uptime, reduced maintenance costs, and fewer environmental breaches (Tayab et al., 2024). These outcomes were attributed to better documentation, streamlined reporting chains, and the proactive identification of hazardous conditions. Moreover, the system facilitated root-cause analysis and process audits, leading to a culture of continual improvement and enhanced decision-making reliability.

Human factors are particularly crucial in this industry. Research by Edirisinghe and Gunathilake (2024) estimates that human error accounts for up to 90% of safety-related incidents in oil and gas operations. Recognizing this, organizations have incorporated Human Factors Engineering (HFE) into SMS design, focusing on worker-centered system configurations and safety-conscious job design. Enhanced training simulations, scenario planning, and real-time feedback loops have been effective in reducing the probability of catastrophic events like blowouts. These interventions have also contributed to an organizational culture where safety is viewed as a shared responsibility rather than a top-down mandate.

SMS in the Healthcare Sector

In recent years, healthcare organizations have looked to the aviation industry for inspiration in designing and implementing their own SMS models. This cross-sectoral learning has led to the development of structured incident reporting systems, adverse event analysis procedures, and patient safety checklists modeled after aviation safety protocols (Chen & Bria, 2022; Njoku et al., 2025). Hospitals adopting these approaches have reported improvements in clinical safety and workflow efficiency. For instance, transparent reporting systems have encouraged nurses and physicians to share near-miss events and unintentional errors without fear of retribution, fostering a culture of learning and risk awareness.

The positive outcomes include not only lower rates of adverse medical events but also enhanced patient satisfaction and more robust interdisciplinary coordination. Training programs emphasizing communication, teamwork, and proactive risk identification have become standard in many advanced hospitals, drawing upon simulation practices derived from flight deck management.

Despite these successes, significant barriers remain. Resistance to change is widespread among both clinical and administrative staff. Concerns over increased administrative workload, fear of

punitive repercussions, and limited resource availability have been noted as deterrents to full SMS adoption (Kruszyński & Dawidowicz, 2020; Njoku et al., 2025). To address these challenges, Chen and Bria (2022) emphasized the need for leadership commitment, comprehensive training, and sustained engagement across professional hierarchies. A promising strategy has been the introduction of incentive-based safety participation programs and peer-led workshops to reinforce SMS principles in everyday practice.

Rathore et al. (2024) further found that continuous professional development opportunities, when linked to safety competency assessments, significantly improved adherence to SMS protocols among healthcare providers. These programs not only expanded the technical skill set of participants but also enhanced their understanding of systemic risk, error prevention, and responsive care design.

Global Comparative Insights

Across the four sectors analyzed, geographical context plays a moderating role in SMS effectiveness. Developed countries such as Canada, the United Kingdom, and Japan exhibit high SMS maturity, driven by strict regulatory oversight and advanced technological infrastructures. In contrast, lower-middle-income regions face constraints related to financing, cultural attitudes toward safety, and limited access to real-time data technologies. However, innovations in mobile safety apps, cloud-based monitoring systems, and localized training programs have begun to bridge this gap. For example, in Indonesia's oil and gas sector, adapted SMS frameworks leveraging mobile risk reporting have shown promise in improving field-level safety compliance despite resource limitations (Hadi et al., 2024).

These comparative findings underline the importance of contextual adaptation and cross-industry learning in SMS development. While aviation leads in institutionalized SMS practices, construction, energy, and healthcare sectors are rapidly adopting and customizing these systems to meet their unique operational and cultural needs. The growing recognition of the human element in safety—as both a vulnerability and a strength—underscores a paradigm shift toward more resilient and people-centered safety management frameworks.

The cross-sectoral integration of Safety Management Systems (SMS) reveals both convergence and divergence in application, outcomes, and implementation challenges. Findings from aviation, construction, oil and gas, and healthcare highlight that while SMS principles are widely accepted, their effectiveness is largely contingent upon industry-specific factors, regulatory environments, and organizational culture.

In aviation, SMS is characterized by rigorous standardization and procedural discipline, which are deeply embedded in daily operations and supported by global regulations from organizations such as the International Civil Aviation Organization (ICAO). Studies such as Ciavarelli (2016) and Simsekler et al. (2019) underscore the link between structured incident reporting systems and reduced accident rates, reflecting a matured safety culture reinforced by high compliance and data-driven interventions. This aligns with findings in the healthcare sector, where adaptations of aviation-style SMS have led to improved patient safety outcomes through enhanced reporting transparency and a shift towards non-punitive error management (Chen & Bria, 2022; Njoku et

al., 2025). In both sectors, a strong feedback loop between safety data and operational response contributes significantly to positive safety performance.

Conversely, in construction, SMS integration is challenged by the sector's inherent fragmentation and variability. Unlike aviation or healthcare, construction projects frequently operate under unique, short-term conditions with diverse subcontractors and fluctuating hazards. Xu et al. (2019) and Chen & Bria (2022) indicate that inconsistencies in communication, coupled with limited standardization, hinder the uniform implementation of safety procedures. While ontological frameworks and the HOT (Human-Organizational-Technical) approach have shown promise in streamlining safety data and coordination (Sadeghi et al., 2020; Nabia et al., 2023), the cultural and structural barriers within construction demand more adaptive and decentralized safety strategies.

The oil and gas industry presents another layer of complexity, where high-risk operations necessitate the integration of SMS with Process Safety Management (PSM) systems. This dual-layered approach has been effective in detecting risks early and ensuring procedural integrity, especially in technologically intense environments (Tayab et al., 2024). However, Edirisinghe & Gunathilake (2024) argue that up to 90% of incidents in this industry are attributable to human error, reinforcing the need for safety systems that go beyond technical design and address human behavior and training. The inclusion of Human Factors Engineering (HFE) and simulation-based drills illustrates how behavioral insights are increasingly critical to SMS success in energy sectors.

These sectoral comparisons suggest that successful SMS implementation depends on both contextual customization and systemic readiness. Factors such as management commitment, employee engagement, and technological infrastructure vary significantly across industries and influence how SMS is perceived, adopted, and internalized. In aviation and healthcare, centralized oversight and professionalized workforces create favorable conditions for structured safety systems. In contrast, construction's decentralized operations and energy's technical hazards require more flexible and responsive models.

Leadership remains a cornerstone of effective SMS across all sectors. As emphasized by Hignett et al. (2016) and Markowski et al. (2021), the active involvement of top management is not only essential in policy formulation but also in resource allocation, training provision, and the normalization of safety reporting. In organizations where leadership visibly prioritizes safety, employees are more likely to participate in safety programs and report hazards, fostering a bottom-up reinforcement of the safety culture. The absence of leadership commitment, on the other hand, often leads to resource constraints, neglect of procedural updates, and marginalization of safety concerns in strategic planning.

Safety culture itself is a pivotal systemic element. The presence of a supportive and transparent safety environment encourages learning from incidents rather than punitive measures. This cultural dynamic, when present, reduces underreporting and enables continuous improvement. Hajiyeva et al. (2023) and Tayab et al. (2024) support this claim by showing how robust safety cultures are associated with lower incident rates and greater system resilience. However, culture cannot be imported—it must be cultivated internally through role modeling, incentives, and participatory safety planning.

Another critical factor is training and workforce capability. The success of any SMS hinges on the workforce's ability to understand, internalize, and apply safety protocols in real scenarios. Kruszyński & Dawidowicz (2020) and Ciavarelli (2016) point out that safety training is most effective when it goes beyond rule memorization and incorporates situational judgment, emergency simulation, and scenario-based learning. These forms of training empower workers to respond dynamically, rather than mechanically, to risk events. Nonetheless, in sectors with transient or less-educated workforces, such as construction, training systems must be adjusted for accessibility and language barriers.

Technology integration has become a double-edged sword in SMS implementation. On one hand, data analytics, digital twins, and predictive modeling enhance risk identification and decision-making (Sia et al., 2024). On the other, in industries or regions where digital infrastructure is lacking or fragmented, these technologies may not be fully operationalized. Poorly integrated systems lead to data silos, delayed incident response, and inconsistent safety performance. Therefore, the successful use of technology in SMS requires an ecosystem that supports interoperability, data literacy, and investment in digital tools.

Stakeholder involvement, especially in sectors with complex supply chains like construction and oil and gas, is essential for SMS success. Xu et al. (2019) highlight the value of collaborative risk assessments that involve contractors, suppliers, and regulators. This holistic engagement fosters a more accurate understanding of hazards and enables the design of shared safety goals. Where stakeholder coordination is weak, SMS implementations often fail to capture operational realities, resulting in noncompliance and procedural fatigue.

The influence of national policies and international regulations cannot be overlooked. Standards such as ISO 45001 provide a globally recognized benchmark for SMS, aiding organizations in aligning internal systems with external expectations (Tayab et al., 2024). Governmental enforcement and industry-specific mandates create pressure for organizations to invest in SMS and provide the legal grounding for compliance monitoring. In highly regulated environments, such as European aviation or healthcare, SMS outcomes are more favorable due to the alignment of incentives and oversight. In contrast, countries with weak regulatory enforcement tend to see SMS treated as a symbolic or checkbox exercise rather than a substantive operational commitment (Chen & Bria, 2022).

Public policy also shapes innovation trajectories. Governments that fund safety technology research and provide tax incentives for training investments indirectly bolster SMS effectiveness. Karevan & Nadeau (2024) emphasize how government-supported pilot programs in data-driven safety systems have led to industry-wide transformations. Furthermore, comparative international studies reveal that countries with proactive policies and public-private safety partnerships outperform others in both accident prevention and operational sustainability (Hajiyeva et al., 2023).

Despite these insights, current research on SMS integration presents notable limitations. Much of the literature is sector-specific, lacking comparative analysis that might illuminate cross-sectoral best practices. Tayab et al. (2024) and Chen & Bria (2022) call for studies that systematically examine how SMS approaches succeed or fail across industries and geographies. Moreover, there is a tendency to focus on successful implementations, leaving a knowledge gap regarding failed

SMS integrations and the lessons therein. This success bias limits the generalizability of findings and obscures barriers that persist in lower-resource settings or informal economies.

Finally, while SMS research increasingly acknowledges the human element, few studies have developed integrated frameworks that combine technical safety measures with behavioral science. Future research must explore how cognitive load, decision fatigue, and motivational psychology influence safety behavior, especially under high-pressure or resource-constrained conditions. Expanding the research scope to include social psychology, system dynamics, and organizational behavior will enrich the understanding of what makes SMS not only implemented, but truly effective.

CONCLUSION

This narrative review highlights the varied integration and effectiveness of Safety Management Systems (SMS) across aviation, construction, oil and gas, and healthcare sectors. Key findings reveal that industries with standardized protocols and strong leadership commitment, such as aviation and healthcare, have shown significant reductions in accidents and enhanced safety reporting cultures. Conversely, construction and energy sectors face greater challenges due to contextual complexities, operational fragmentation, and resistance to procedural change. Systemic factors such as management support, safety culture, training quality, technological readiness, and stakeholder engagement strongly influence SMS implementation outcomes.

The urgency to strengthen SMS integration is underscored by persistent incidents and preventable safety failures across high-risk industries. Effective safety strategies must be context-sensitive yet guided by shared best practices. Policymakers are urged to develop flexible and adaptive safety regulations that reflect sector-specific needs while encouraging cross-sectoral learning and technological innovation. Emphasis should be placed on participatory safety planning, leadership training, and embedding human factors engineering into system design.

Future research should address current gaps by conducting comparative cross-industry studies, exploring failed SMS implementations, and integrating behavioral and organizational sciences into safety frameworks. By improving the adaptability and inclusiveness of SMS, organizations can better protect their workforce, optimize operations, and contribute to a culture of proactive risk management in an increasingly complex industrial landscape.

REFERENCE

Akram, A., & Affandi, B. (2024). Uncovering synergies: A comprehensive case study on incorporating API Q2 into an upstream provider's integrated management framework with a focus on ISO14001 and ISO45001. https://doi.org/10.2118/220310-ms

Alizadehsalehi, S., Yitmen, İ., Çelik, T., & Arditi, D. (2018). The effectiveness of an integrated BIM/UAV model in managing safety on construction sites. *International Journal of Occupational Safety and Ergonomics, 26*(4), 829–844. https://doi.org/10.1080/10803548.2018.1504487

Bakar, A., Jamaluddin, M., Musa, R., Fuenmayor, R., Trivedi, R., Mokhlis, M., … & Kamarulzaman, A. (2021). Connecting reservoir, wells, facilities management, HSEE to accelerate data-driven value: Digital fields expansion. https://doi.org/10.2118/204841-ms

Boudreaux, A., & Vetter, T. (2013). The creation and impact of a dedicated section on quality and patient safety in a clinical academic department. *Academic Medicine, 88*(2), 173–178. https://doi.org/10.1097/acm.0b013e31827b53dd

Chen, W., & Bria, T. (2022). A review of ontology-based safety management in construction. *Sustainability, 15*(1), 413. https://doi.org/10.3390/su15010413

Ciavarelli, A. (2016). Integration of human factors into safety and environmental management systems. https://doi.org/10.4043/27015-ms

Edirisinghe, R., & Gunathilake, L. (2024). An IoT-based heat stress management system for the construction industry. *Engineering Construction & Architectural Management*. https://doi.org/10.1108/ecam-06-2024-0813

Hadi, M., Sugiono, B., Mizar, M., Witjoro, A., & Irvan, M. (2024). Enhancing low-temperature long-time milk pasteurization process with a C4.5 algorithm-driven AIoT system for real-time decision-making. *Journal of Food Process Engineering, 47*(4). https://doi.org/10.1111/jfpe.14606

Hajiyeva, A., Mammadova, U., Tanriverdiyeva, G., & Коваленко, О. (2023). Technological innovations in agriculture: Impact on production efficiency. *Scientific Horizons, 27*(1), 172–182. https://doi.org/10.48077/scihor1.2024.172

Herkenhoff, B., Zagrai, A., Zagrai, A., & Hassanalian, M. (2023). Integration of drones with 5G connectivity to airfields for enhancing mission readiness and structural health monitoring. https://doi.org/10.2514/6.2023-3784

Hignett, S., Lang, A., Pickup, L., Ives, C., Fray, M., McKeown, C., … & Bowie, P. (2016). More holes than cheese: What prevents the delivery of effective, high quality and safe health care in England? *Ergonomics, 61*(1), 5–14. https://doi.org/10.1080/00140139.2016.1245446

Karevan, A., & Nadeau, S. (2024). A comprehensive STPA-PSO framework for quantifying smart glasses risks in manufacturing. *Heliyon, 10*(9), e30162. https://doi.org/10.1016/j.heliyon.2024.e30162

Koimtzoglou, A., Ventikos, N., Routsis, D., & Louzis, K. (2024). Risk analysis on autonomous vessels based on systems theory – Application of NET-HARMS method. *Journal of Physics Conference Series, 2867*(1), 012046. https://doi.org/10.1088/1742-6596/2867/1/012046

Kruszyński, W., & Dawidowicz, J. (2020). Computer modeling of water supply and sewerage networks as a tool in an integrated water and wastewater management system in municipal enterprises. *Journal of Ecological Engineering, 21*(2), 261–266. https://doi.org/10.12911/22998993/117533

Leblanc, L., Kresic, W., Keane, S., & Munro, J. (2016). Advanced integrity management framework for pipelines. https://doi.org/10.1115/ipc2016-64609

Markowski, A., Krasławski, A., Vairo, T., & Fabiano, B. (2021). Process safety management quality in industrial corporation for sustainable development. *Sustainability, 13*(16), 9001. https://doi.org/10.3390/su13169001

Nabia, S., Wonodi, C., Vilajeliu, A., Sussman, S., Olson, K., Cooke, R., … & Lindstrand, A. (2023). Experiences, enablers, and challenges in service delivery and integration of COVID-19 vaccines: A rapid systematic review. *Vaccines, 11*(5), 974. https://doi.org/10.3390/vaccines11050974

Njoku, J., Nkoro, E., Medina, R., Nwakanma, C., Lee, J., & Kim, D. (2025). Leveraging digital twin technology for battery management: A case study review. *IEEE Access, 13*, 21382–21412. https://doi.org/10.1109/access.2025.3531833

Rasmuson, E., Korchevskiy, A., Duane, A., Haugh, A., & Funk, S. (2015). Development of the three-dimensional hazard and risk assessment methodology for health and safety management systems in petroleum industry. https://doi.org/10.2118/174120-ms

Rathore, S., Gupta, A., Parashar, A., Upadhyay, D., Deb, R., & Gupta, A. (2024). Machine learning in predictive maintenance for industrial equipment. https://doi.org/10.1109/icac2n63387.2024.10895271

Sadeghi, H., Mohandes, S., Hosseini, M., Banihashemi, S., Mahdiyar, A., & Abdullah, A. (2020). Developing an ensemble predictive safety risk assessment model: Case of Malaysian construction projects. *International Journal of Environmental Research and Public Health, 17*(22), 8395. https://doi.org/10.3390/ijerph17228395

Santos, Â., Melo, R., Clemente, T., & Santos, S. (2021). Integrated management system: Methodology for maturity assessment in food industries. *Benchmarking: An International Journal, 29*(6), 1757–1780. https://doi.org/10.1108/bij-05-2021-0280

Sia, W., Ahmad, Z., Muhamad, S., Ali, A., & Hamdan, H. (2024). Effective risk management through data-driven HSE assurance program for safe execution project delivery. https://doi.org/10.2118/221994-ms

Simsekler, M., Gürses, A., Smith, B., & Ozonoff, A. (2019). Integration of multiple methods in identifying patient safety risks. *Safety Science, 118*, 530–537. https://doi.org/10.1016/j.ssci.2019.05.057

Tayab, M., Suwaidi, H., Lari, M., Kumar, P., & Shah, V. (2024). Navigating through operations excellence, process safety and sustainability in upstream & downstream segments of oil & gas operations with resilience and responsibility to prevent incidents. https://doi.org/10.2118/222010-ms

Toyserkani, G., Huynh, L., & Morrato, E. (2020). Adaptation for regulatory application: A content analysis of FDA risk evaluation and mitigation strategies assessment plans (2014–2018) using RE-AIM. *Frontiers in Public Health, 8*. https://doi.org/10.3389/fpubh.2020.00043

Xu, Q., Chong, H., & Liao, P. (2019). Collaborative information integration for construction safety monitoring. *Automation in Construction, 102*, 120–134. https://doi.org/10.1016/j.autcon.2019.02.004

Yunusa-Kaltungo, A., Jungudo, R., Ray, S., & Sokunbi, I. (2022). How do maintenance personnel perceive occupational safety and health (OSH) risks during major overhauls, outages, shutdowns or turnarounds (MOOSTs)? An examination of the Nigerian cement industry. https://doi.org/10.1115/imece2022-89020

Zhang, X., Zhao, K., Li, C., & Li, Y. (2024). Structuring and recommendations for research on the construction of intelligent multi-industry and multihazard emergency planning systems. *Sustainability, 16*(14), 5882. https://doi.org/10.3390/su16145882