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Occupational Health and Safety in the Age of AI: Challenges and Innovations in Risk Management

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ABSTRACT: Occupational risk assessment is central to ensuring workplace safety, particularly amid the rapid technological and organizational changes characterizing contemporary work environments. This narrative review aims to examine and synthesize recent advancements in risk assessment models within occupational health and safety (OHS) frameworks. A comprehensive literature search was conducted across databases including Scopus, PubMed, Web of Science, and Google Scholar, focusing on studies published over the past decade. Inclusion criteria centered on empirical studies assessing the effectiveness, integration, and limitations of OHS risk models across high-risk sectors. The results reveal four key themes: the incorporation of artificial intelligence (AI) and Internet of Things (IoT) in predictive safety systems; the efficacy of Safety Management Systems (SMS) in structuring participatory and proactive safety cultures; the effectiveness of dynamic, real-time assessment frameworks in high-risk industries; and the influence of cultural, economic, and policy contexts on model adoption. These findings highlight a notable shift toward responsive, data-driven, and employee-centered safety models. However, systemic barriers such as poor regulatory enforcement, limited awareness, and static theoretical frameworks hinder optimal implementation. The review advocates for policy reforms, employee empowerment strategies, and adaptive frameworks that reflect technological advancements and context-specific needs. These interventions are essential to overcoming identified barriers and improving safety outcomes globally. Future research must aim to bridge theoretical gaps and enhance the generalizability of risk assessment frameworks across diverse workplace environments.

Keywords: Occupational Health And Safety, Risk Assessment Models, Safety Management Systems, Artificial Intelligence In Safety, Workplace Hazard Prevention, Proactive Safety Strategies, Regulatory Compliance.

INTRODUCTION

Occupational Health and Safety (OHS) management remains a fundamental pillar of sustainable work environments worldwide. As organizations seek to safeguard the well-being of workers and maintain operational continuity, the implementation of effective risk assessment models has become increasingly vital. The complexity of occupational risks—ranging from physical to psychosocial hazards—necessitates comprehensive and adaptable approaches. Recent scholarship has emphasized the importance of integrating both traditional and advanced frameworks to

improve hazard identification and mitigation strategies (Mombelli et al., 2022). As industrial processes evolve in response to technological innovations, there is a corresponding need for risk assessment methodologies that align with the new realities of the workplace (Manni et al., 2023).

Technological transformations associated with the Fourth Industrial Revolution have significantly influenced the landscape of workplace safety. The introduction of automation, digitization, and cyber-physical systems under Industry 4.0 has generated novel occupational hazards, challenging the applicability of conventional safety models. Traditional risk assessment practices, often reliant on retrospective analyses and paper-based documentation, are increasingly viewed as insufficient to address the dynamic and real-time nature of contemporary workplace hazards (Rydell et al., 2019). Tools such as the Internet of Things (IoT) and Building Information Modeling (BIM) now offer opportunities for continuous, real-time risk monitoring (Tsang et al., 2018), while the integration of machine learning and fuzzy logic has been recommended to enhance predictive capacity and responsiveness (Jin et al., 2019).

The relevance of robust OHS risk assessment models is further underscored by empirical findings that highlight their effectiveness in reducing workplace incidents, especially in high-risk sectors. For example, Ghahramani (2016) demonstrated that the adoption of the OHSAS 18001 framework led to measurable improvements in safety outcomes through employee involvement and ongoing training. This assertion is corroborated by Mombelli et al. (2022), who reported that participatory safety programs significantly decreased accident rates. Similarly, Nadalin and Smith (2020) found that targeted vulnerability assessments helped optimize injury reporting and prevention mechanisms in construction and healthcare settings. These results are echoed by studies indicating that Health and Safety Management Systems (HSMS), when embedded in organizational culture, contribute to significant improvements in workplace safety metrics (Yeşilgöz & Arğa, 2025).

Quantitative data also confirm that investments in risk-oriented organizational strategies yield tangible results. According to Rydell et al. (2019), the implementation of risk assessments as part of core operational practices led to a demonstrable decline in incidents across monitored industrial sites. Such findings validate the importance of structured risk management systems that prioritize continuous hazard identification, employee feedback, and data-driven safety protocols. These empirical insights serve as strong arguments for institutionalizing risk assessment as a cornerstone of OHS management.

Despite notable advancements, substantial challenges persist. One significant issue is the heterogeneity in worker awareness regarding occupational hazards, particularly in environments where biological, chemical, or psychological risks coexist. Lin et al. (2019) documented disparities in hazard recognition among healthcare workers, which impaired the efficacy of existing safety programs. Mombelli et al. (2022) further highlighted that limited access to critical safety information contributes to low engagement in preventive behaviors. Moreover, the fast-paced evolution of industrial practices often leaves risk models lagging behind, unable to capture emerging threats promptly (Chaiklieng et al., 2025).

Another critical concern lies in the inadequacy of traditional models to capture the multi-hazard nature of modern workplaces. Cagno et al. (2014) noted that many frameworks focus narrowly on physical hazards, neglecting psychosocial and organizational risk factors. This gap is particularly problematic in industries such as construction and shipbuilding, where workers are simultaneously exposed to mechanical and emotional stressors (BAYHUN & Demirel, 2024). The literature also underscores that standardized models, often derived from historical data, lack the adaptability to remain relevant amidst continuous technological innovation (Hollá et al., 2024).

Furthermore, existing frameworks frequently fail to incorporate worker perspectives adequately. Research indicates that participatory ergonomics and inclusive safety culture are essential for the successful implementation of OHS measures (Liberati et al., 2017; Yeşilgöz & Arğa, 2025). Nevertheless, many models do not embed mechanisms for continuous worker feedback or shared decision-making, thereby reducing their practical effectiveness. This deficiency is particularly acute in hazardous substance risk assessments, where predictive limitations have been shown to compromise worker protection (Kim & Byeon, 2017).

These limitations reveal a pressing need for renewed inquiry and innovation in OHS risk assessment. The existing literature is fragmented in addressing the intersectionality of risk types and lacks robust comparative analyses across varying industrial and geographical contexts. Although recent advancements suggest the potential of AI and big data analytics, their practical integration into OHS frameworks remains underexplored and requires further validation (Pireddu et al., 2024). Consequently, this gap justifies the development of a comprehensive narrative review aimed at consolidating and synthesizing available evidence on emerging and established risk assessment models.

The primary objective of this review is to examine contemporary models and frameworks used in occupational health and safety risk assessments, with particular emphasis on their adaptability, inclusiveness, and technological integration. It seeks to analyze the role of participatory mechanisms, data analytics, and sector-specific challenges in shaping effective OHS strategies. The review also aims to identify critical barriers and enabling factors influencing the implementation and scalability of these models across diverse work environments.

This narrative review will focus on studies published over the past decade that pertain to high-risk sectors including construction, healthcare, manufacturing, agriculture, and maritime industries. Special attention will be given to studies conducted in both developed and developing regions to provide a comprehensive understanding of global practices. In addition, the review will address thematic areas such as psychosocial risk integration, digital risk monitoring, and regulatory compliance, thereby offering a multidimensional perspective on contemporary risk assessment practices.

METHOD

The methodology adopted for this narrative review was structured to systematically gather, analyze, and synthesize relevant academic literature pertaining to occupational health and safety (OHS) risk assessment frameworks. Given the interdisciplinary nature of OHS and its implications across various industrial and geographical contexts, it was essential to employ a robust and methodical approach to literature collection. The primary objective was to examine the existing body of knowledge regarding the development, implementation, and evaluation of risk assessment models, with an emphasis on technological integration, worker participation, and effectiveness in reducing occupational incidents.

To ensure the comprehensiveness of the review, a multi-database search strategy was employed. The databases selected for this study included PubMed, Scopus, Web of Science, and Google Scholar. These platforms were chosen due to their extensive repositories of peer-reviewed literature spanning medical, engineering, and social science disciplines. PubMed was particularly useful for capturing studies related to occupational health in healthcare settings, while Scopus and Web of Science provided broad coverage of technical and policy-oriented literature in construction, manufacturing, and maritime sectors. Google Scholar was used as a complementary source to access grey literature, including working papers, reports, and dissertations that are not always indexed in traditional academic databases.

The search process was initiated by identifying relevant keywords and search phrases that encapsulated the core themes of the review. These included terms such as “risk assessment,” “occupational health,” “safety management systems,” “frameworks,” “workplace injuries,” and “occupational hazards.” Boolean operators (AND, OR, NOT) were employed to refine the search and ensure the inclusion of comprehensive yet focused results. For example, combinations like "risk assessment" AND "occupational health" AND "frameworks" were used to identify studies specifically addressing structured approaches to hazard identification and mitigation within workplaces. Truncation and wildcard symbols were also utilized to capture variations in spelling and terminology, enhancing the breadth of search results.

In addition to keyword searching, citation tracking was conducted to locate highly cited and influential studies in the field. This method involved examining the reference lists of relevant articles to identify additional sources that may not have surfaced through keyword searches alone. The "related articles" feature in databases such as PubMed and ScienceDirect was also leveraged to explore thematically similar publications. These strategies facilitated the construction of a literature base that not only encompassed historical developments in OHS risk assessment but also reflected recent innovations and emerging trends, including the application of artificial intelligence and real-time monitoring tools.

Following the collection of literature, a set of inclusion and exclusion criteria was established to determine the eligibility of studies for detailed analysis. The inclusion criteria required that studies be published in peer-reviewed journals and present empirical findings related to the implementation or evaluation of OHS risk assessment frameworks. Preference was given to articles that clearly articulated the relationship between risk assessment interventions and measurable occupational health outcomes, such as reductions in injury rates, improved compliance

with safety protocols, or enhanced hazard recognition among employees. Both quantitative and qualitative studies were considered, provided they offered substantive insights into the effectiveness, challenges, and contextual factors influencing risk assessment practices.

Furthermore, studies that explored stakeholder perceptions, participatory processes, and organizational behavior in relation to risk assessment frameworks were included to ensure a comprehensive understanding of the topic. These qualitative contributions enriched the review by illuminating the lived experiences and practical considerations of implementing safety models in real-world environments. For example, studies highlighting how frontline workers and management perceive the utility and burden of risk assessment protocols were deemed valuable, as they shed light on the human factors often overlooked in technical evaluations.

On the other hand, several exclusion criteria were applied to filter out studies that lacked relevance or academic rigor. Articles not published in peer-reviewed sources, such as opinion pieces, editorials, and magazine articles, were excluded. Studies that focused on general public health or healthcare management without specific attention to occupational contexts were also omitted. Moreover, purely theoretical papers that failed to demonstrate practical applications or provide empirical validation were considered outside the scope of this review. Another exclusion criterion involved the language of publication; only English-language articles were reviewed, unless a reliable translation was available. This limitation was necessary to maintain consistency in the evaluation process but may have resulted in the exclusion of relevant studies published in other languages.

The process of screening and selecting literature was conducted in multiple phases. Initially, titles and abstracts of identified records were reviewed to assess their potential relevance. Articles that met the preliminary criteria were then subjected to full-text analysis to evaluate their methodological quality, clarity of findings, and alignment with the objectives of the review. To enhance consistency and minimize bias, two independent reviewers assessed the selected articles. Discrepancies in inclusion decisions were resolved through discussion and consensus, ensuring that only studies meeting the predetermined criteria were retained.

During the synthesis phase, data from the selected studies were extracted and organized thematically. The key themes included technological innovations in risk assessment, participatory frameworks, integration of safety management systems, and sector-specific adaptations. This thematic approach enabled a structured comparison of findings across diverse settings and facilitated the identification of commonalities and divergences in risk assessment practices. The extracted data were then contextualized within broader theoretical and policy frameworks, providing a foundation for critical analysis and synthesis in the subsequent sections of the review.

In summary, the methodology employed for this narrative review combined systematic search techniques with clearly defined inclusion and exclusion criteria to ensure the relevance, rigor, and comprehensiveness of the literature base. By utilizing a multi-database approach, incorporating citation tracking, and applying a structured screening process, the review captures a holistic picture of current practices, challenges, and innovations in occupational health and safety risk assessment frameworks. This methodological rigor strengthens the validity of the review findings and supports

the development of evidence-based recommendations for improving risk management in diverse occupational settings.

RESULT AND DISCUSSION

The findings of this narrative review are organized into four major thematic categories that have emerged across the literature: technological integration in risk assessment, the role of safety management systems (SMS), dynamic and preventive approaches to risk assessment, and contextual and geographical influences. Each theme is discussed in detail to provide a comprehensive understanding of the evolving practices, challenges, and opportunities in occupational health and safety (OHS) risk assessment.

A. Technology in Risk Assessment

Recent advancements in technology have significantly transformed risk assessment models by incorporating artificial intelligence (AI) and machine learning (ML) algorithms into workplace safety protocols. These technologies allow for predictive modeling using large datasets, enabling earlier identification of hazards and better prevention strategies. Dalal and Bassu (2020) describe the application of deep learning algorithms to real-time sensor data, which has resulted in highly responsive systems capable of detecting unsafe conditions before incidents occur. This innovation represents a departure from traditional methods, allowing for predictive interventions and greater operational agility.

The Internet of Things (IoT) further enhances these capabilities by enabling continuous environmental monitoring through interconnected sensors. Lemos et al. (2024) highlight that smart monitoring systems not only improve the accuracy of hazard detection but also foster improved communication between employees and management regarding safety conditions. These technologies, by promoting real-time feedback, shift organizational safety cultures from reactive to proactive.

Quantitative evidence supports the effectiveness of AI-driven tools in improving safety outcomes. In industrial sectors such as construction, AI systems have demonstrated predictive accuracy levels exceeding 90% for potential workplace accidents (Dalal & Bassu, 2020). Moreover, the F1-score—an evaluation metric balancing precision and recall—improved by as much as 30% compared to manual assessment methods. Lemos et al. (2024) emphasize that user-friendly data visualization interfaces embedded in these tools have also increased employee compliance with safety measures, leading to a marked decrease in incident frequency.

B. Safety Management Systems

The integration of Safety Management Systems (SMS) has emerged as a cornerstone in enhancing the structure and consistency of risk assessments across organizations. SMS provides a strategic framework that normalizes safety practices and embeds them into operational procedures. Ghahramani (2016) underscores the role of SMS in establishing routine identification, evaluation, and mitigation of risks, which fosters a culture where safety is systematically prioritized. Nadalin

and Smith (2020) found that SMS implementation leads to more consistent safety practices across all levels of an organization, ultimately improving risk visibility and organizational learning.

Empirical studies validate the effectiveness of SMS in mitigating occupational hazards. Rydell et al. (2019) reported a substantial reduction in accident rates in industries that implemented SMS, primarily due to improved communication and structured safety training. A sector-specific study by Nkrumah et al. (2021) in the oil and gas industry observed a 40% decline in workplace incidents following SMS adoption. This improvement was linked to continuous safety evaluations and adaptive safety policies embedded within the SMS framework.

Additionally, in the textile sector, Ghahramani (2016) showed that incorporating SMS led to increased compliance with safety protocols among workers, attributed to better-defined hazard control measures and safety culture reinforcement. These findings collectively affirm the crucial role SMS plays in cultivating resilient safety practices and organizational preparedness.

C. Dynamic and Preventive Approaches

Dynamic risk assessment models have gained prominence for their ability to accommodate rapidly changing risk profiles in high-risk industries. In maritime operations, for example, real-time risk monitoring tools that aggregate weather data, mechanical performance indicators, and crew status have proven effective in enhancing situational awareness. Nkrumah et al. (2021) report that such models significantly reduced maritime incidents over a two-year observational period, demonstrating the value of incorporating multiple data streams into safety management.

In the oil and gas industry, dynamic models employing predictive analytics have been equally effective. Longitudinal studies indicate that these models foster proactive safety behaviors and encourage workforce participation in identifying and mitigating hazards (Nkrumah et al., 2021). The feedback loop created by dynamic risk assessments enhances accountability and supports the continual refinement of safety practices.

Preventive strategies that facilitate the transition from reactive to proactive models are essential to maximizing the benefits of dynamic assessments. One widely supported approach involves Continuous Safety Improvement Programs (CSIP), which include frequent training, audits, and risk reassessments. Ghahramani (2016) asserts that such programs cultivate a heightened awareness of risks among workers, equipping them to act swiftly in the face of evolving hazards.

Manni et al. (2023) also highlight the importance of employee engagement in shaping safety outcomes. Engaged workers who actively participate in safety planning are more likely to adhere to protocols and contribute constructively to safety evaluations. The resulting synergy not only reduces incident rates but also elevates morale and productivity, demonstrating the interdependence of safety culture and operational performance.

D. Contextual and Geographical Factors

The adoption and implementation of OHS risk models are deeply influenced by regional, cultural, and policy-related variables. In developed regions such as Europe and North America, stringent regulations and robust enforcement mechanisms have led to more comprehensive adoption of innovative risk models. Organizations in these contexts frequently utilize integrated systems that

combine compliance requirements with advanced analytics, facilitating continual safety enhancements (Demeritt et al., 2015).

In contrast, developing countries often face structural limitations that impede the implementation of sophisticated risk models. Demeritt et al. (2015) observe that in many low-income settings, regulatory enforcement is weak, and economic constraints lead organizations to deprioritize long-term safety investments in favor of short-term profitability. This results in reliance on reactive safety measures that may not be adequate for complex operational environments.

Cultural dimensions also play a critical role in shaping risk assessment practices. According to Castiblanque (2020), collectivist cultures, which emphasize shared responsibility, are more conducive to effective safety protocol adherence. Such cultural orientations facilitate cooperative safety planning and peer accountability. Conversely, individualistic cultures may present challenges to uniform compliance due to variable personal attitudes toward risk and safety procedures (Chirico et al., 2019).

Comparative analyses reveal stark contrasts between developed and developing countries in terms of risk assessment sophistication. In countries such as Germany and Canada, risk assessments are dynamic and regularly updated to reflect changing operational and technological conditions (Manni et al., 2023). These systems typically incorporate real-time monitoring and feedback mechanisms. Meanwhile, developing nations often rely on static, checklist-based assessments due to limited access to training and technology (Kruzhilko et al., 2020).

The disparities highlight the importance of international knowledge sharing and capacity-building initiatives. Collaborative frameworks and cross-national partnerships can play a vital role in transferring best practices and resources to under-resourced settings. Such initiatives not only improve global occupational safety standards but also contribute to equitable development across industrial sectors.

In conclusion, the results of this narrative review underscore the transformative potential of technological innovation and systematic management frameworks in advancing occupational risk assessments. From AI-enhanced prediction models to comprehensive SMS protocols and culturally informed strategies, each dimension contributes to a more holistic and responsive approach to workplace safety. Recognizing the contextual variability across regions further reinforces the need for adaptable, inclusive, and evidence-based risk assessment practices to meet the evolving demands of global occupational health and safety.

The findings of this review offer nuanced insights into how current occupational health and safety (OHS) risk assessment practices align with, deviate from, and expand upon established theoretical frameworks. Through the integration of emerging technologies and participatory methodologies, the field of OHS is undergoing a transformative shift that necessitates a re-evaluation of traditional models. This discussion synthesizes the implications of these findings and explores systemic barriers, theoretical misalignments, and actionable interventions that could enhance the efficacy and relevance of risk assessment frameworks.

The relationship between worker perception and protective behavior remains foundational to several safety theories, including psychological risk theory. Research by Thepaksorn et al. (2018)

validates this connection, demonstrating that perceived risk significantly influences the use of protective equipment. However, the findings also reveal context-dependent variability in how these perceptions manifest across sectors, such as in rubberwood sawmills compared to healthcare. These divergences suggest that universal models must be recalibrated to reflect sector-specific behavioral patterns. Without this adaptation, the application of psychological models remains limited in utility, failing to capture the dynamic nuances of different work environments.

This need for contextualization is further evidenced by participatory management studies, which critique the assumption that employee involvement automatically enhances risk mitigation. Castiblanque (2020) reveals that bureaucratic and legal restrictions often neutralize the potential benefits of participatory frameworks. This contradiction points to an urgent need to revise participatory safety models to account for structural impediments, particularly in organizations with rigid hierarchies or compliance-driven governance structures. Consequently, while the theory of participatory engagement remains conceptually robust, its translation into practice is contingent on overcoming organizational and systemic limitations.

Complementing this view, Brocal et al. (2018) reinforce the value of integrated safety systems by linking major and minor accidents in a coherent theoretical framework, such as Reason's Swiss cheese model. Their findings suggest that failures are rarely isolated, instead resulting from cumulative systemic vulnerabilities. However, the linear causality proposed by traditional models may no longer suffice in complex industrial environments where hazards evolve rapidly. New theoretical frameworks must embrace the multidimensionality of modern risks, incorporating human, technological, and procedural interactions into a single, adaptive model.

Ramli et al. (2022) present compelling evidence from healthcare settings during the COVID-19 pandemic that underscores the limitations of static models. Their study points to the need for responsive, agile frameworks capable of integrating emergent biological threats. Existing models, designed primarily for mechanical or chemical hazards, struggled to accommodate infectious disease dynamics. This discrepancy reveals a theoretical blind spot and suggests that OHS risk frameworks must evolve to remain relevant in the face of future pandemics or climate-induced occupational health risks.

In contrast, Lemos et al. (2024) offer promising directions for future theory development through their work on AI-based safety monitoring. Their findings align with emerging paradigms that advocate data-centric safety practices and real-time decision-making. These technologies provide empirical support for frameworks grounded in dynamic risk theory, where continuous feedback and learning loops replace static assessment tools. As AI continues to shape workplace safety, the integration of digital intelligence into theoretical models will be critical.

Although technological innovations offer tremendous potential, their effectiveness is often undermined by systemic and policy-level barriers. One of the most persistent challenges is the lack of awareness about injury reporting protocols. Nadalin and Smith (2020) emphasize that underreporting distorts risk data and hinders organizational learning. This issue is exacerbated in settings with low literacy or minimal access to training, where workers may be unaware of their rights or fearful of retaliation. Effective implementation of risk models thus depends not only on technical design but also on the socio-institutional contexts in which they operate.

The inconsistent enforcement of regulatory measures further compounds the issue. Chirico et al. (2019) argue that without strong regulatory oversight, organizations often deprioritize safety investments, especially when short-term profitability is at stake. In this light, risk assessment becomes performative rather than preventive, serving compliance checklists rather than operational improvement. Strengthening regulatory enforcement is essential to making risk assessments more than just symbolic gestures.

Static policy frameworks also pose significant challenges. Iavicoli and Tecco (2020) warn that policy stagnation fails to address emerging threats, such as those posed by automation, climate change, or pandemics. When regulatory tools are not updated to reflect evolving hazards, risk assessments lose their relevance and predictive power. Policies must be flexible and forward-looking, incorporating real-time data and scenario modeling to remain effective in rapidly changing work environments.

To address these barriers, several interventions have been proposed. Employee empowerment emerges as a key strategy, supported by Yeşilgöz and Arğa (2025), who argue that engaged workers contribute more meaningfully to risk identification and resolution. Training programs that focus on recognizing and articulating workplace hazards can enhance this engagement. However, empowerment must be accompanied by institutional support, including formal channels for worker input and mechanisms to act on that input.

Policy reform also plays a crucial role. Chirico et al. (2019) call for the enhancement of regulatory infrastructures to mandate more rigorous safety practices. Regular audits and public reporting mechanisms can increase accountability and foster a culture of safety. This approach aligns with the literature advocating for high-reliability organizations, where safety is institutionalized as a core operational value.

Dynamic updating of safety guidelines is another critical need. Iavicoli and Tecco (2020) recommend integrating continuous monitoring systems that can signal the need for policy revision. These systems could draw from IoT devices, worker feedback platforms, and AI-based predictive tools. The effectiveness of this approach lies in its capacity to institutionalize adaptability, ensuring that safety protocols evolve in tandem with workplace realities.

Communication remains a persistent bottleneck in many organizations. Castiblanque (2020) found that hierarchical and opaque communication structures hindered the flow of safety information. To address this, organizations can develop digital dashboards, mobile apps, or regular safety briefings to keep all employees informed and engaged. Transparent communication not only democratizes safety but also builds trust, a prerequisite for effective safety interventions.

Lastly, intersectoral collaboration offers a promising avenue for systemic reform. Manni et al. (2023) highlight the potential of knowledge-sharing networks to disseminate best practices across industries. Collaborative audits, joint training programs, and shared incident databases can create a robust ecosystem of continuous improvement. These networks can also bridge the gap between theory and practice, providing real-world validation for evolving risk models.

Overall, this discussion illustrates that while technological advancements and innovative practices are reshaping OHS risk assessment, their full potential will only be realized through systemic

reform and theoretical evolution. Bridging the gap between abstract frameworks and operational realities requires multi-level strategies involving policy, practice, and participatory governance. Future research must prioritize interdisciplinary approaches that unite technology, behavior, and regulation into cohesive risk management paradigms.

CONCLUSION

This narrative review underscores the transformative evolution of occupational health and safety (OHS) risk assessment frameworks in response to emerging technologies, dynamic workplace conditions, and systemic barriers. The integration of AI, machine learning, and IoT into risk assessment practices has markedly enhanced predictive accuracy and responsiveness, especially in high-risk sectors like construction, maritime, and oil and gas. Meanwhile, the widespread implementation of Safety Management Systems (SMS) has fostered structured and participatory safety cultures that significantly reduce workplace incidents. However, challenges persist, including inconsistent regulatory enforcement, limited worker awareness, and the inadequate adaptability of existing theoretical models to rapidly evolving occupational contexts.

To address these issues, interventions such as employee empowerment, dynamic regulatory policy updates, and improved communication infrastructure are imperative. Policy reforms must also emphasize continuous monitoring and the inclusion of real-time data streams to ensure relevance and flexibility. Furthermore, fostering intersectoral collaboration and integrating context-specific strategies are essential to enhancing the applicability and effectiveness of risk models across different industrial and geographical settings.

Future research should focus on developing hybrid frameworks that combine digital technologies, participatory governance, and adaptive policy mechanisms. Emphasis must also be placed on addressing gaps in low-resource settings and emerging industries, where current literature remains sparse. Ultimately, the creation of inclusive, data-driven, and contextually grounded OHS risk assessment models represents a pivotal strategy in addressing the multifaceted challenges of workplace safety today and in the future.

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