CARITAS UNIVERSITY AMORJI-NIKE, EMENE, ENUGU STATE

Caritas Journal of Engineering Technology

CJET, Volume 5, Issue 1 (2026)

Article History: ***Received:14th Jan., 2026 Revised:22nd Feb., 2026 Accepted:2nd March, 2026***

Technology-Driven OHSM Frameworks for Sustainable Engineering

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Abstract
This research explores the integration of emerging technologies—Artificial Intelligence, Internet of Things, Building Information Modeling, wearables, and blockchain—into Occupational Health and Safety Management (OHSM) to foster sustainable engineering practices in construction and manufacturing. Through a mixed-methods synthesis of recent studies, the research reveals that these technologies enable proactive safety management, reducing workplace incidents by 10–20% via real-time monitoring and predictive analytics, while enhancing sustainability by cutting construction waste by 10%. Despite these advances, high costs, technical expertise gaps, data privacy concerns, and regional disparities hinder adoption, particularly for small enterprises and developing nations. The study's novelty lies in its interdisciplinary approach, bridging OHSM, technology, and sustainability to propose scalable frameworks that address these barriers. It fills critical research gaps, including the lack of theoretical models and longitudinal data, by offering context-specific strategies and stakeholder collaboration models. Results underscore the transformative potential of technology-driven OHSM, providing actionable insights for practitioners and policymakers to institutionalize safer, sustainable workplaces globally.

Keywords: ***Occupational Health and Safety, Sustainability, AI, IoT, BIM, Engineering Management.***

1. Introduction

Occupational Health and Safety Management (OHSM) is a cornerstone of engineering disciplines, ensuring worker safety, improving operational efficiency, and advancing sustainability in high-risk industries such as construction, manufacturing, and industrial operations (Vitrano et al., 2024). The integration of emerging technologies like Artificial Intelligence (AI), the Internet of Things (IoT), and blockchain presents transformative opportunities to enhance OHSM, aligning it with global sustainability frameworks, including the Sustainable Development Goals (SDGs) (Vitrano et al., 2024; Shahid et al., 2025). Industry 4.0 technologies enable real-time hazard monitoring, predictive risk analytics, and improved compliance mechanisms (Bérastégui, 2024; Chaaya et al., 2025). For example, IoT-powered wearable sensors provide continuous workplace surveillance, AI-driven deep learning models predict occupational hazards to reduce accidents in construction and manufacturing, and blockchain ensures supply chain transparency and safety data integrity, particularly in modular construction projects (Davoudi Kakhki et al., 2025; Junjia et al., 2025; Li et al., 2022; Wu et al., 2022).

Despite these advancements, institutionalizing technology-driven OHSM faces significant barriers, including high implementation costs, lack of technical expertise, data privacy concerns, and organizational resistance to change (Kunodzia et al., 2024; Tabatabaee et al., 2022). These challenges are particularly pronounced in developing economies, where infrastructural deficits and weak regulatory frameworks limit technology adoption (Fayyaz et al., 2025; Ndanguza, 2025). While pilot projects in developed regions demonstrate successful technology integration, scaling these solutions to diverse global contexts remains challenging, highlighting the need for context-specific frameworks and robust policy support (Chaaya et al., 2025; Tannous et al., 2025).

The literature identifies multiple obstacles to technology-driven OHSM. High costs of AI and IoT deployment, coupled with the need for specialized training, pose significant hurdles, especially for small and medium enterprises (SMEs) (Basiru et al., 2023; Kunodzia et al., 2024). Privacy concerns related to IoT data collection and ethical issues surrounding AI-driven surveillance create tensions between safety and worker rights (Xu et al., 2022; Bérastégui, 2024). Organizational resistance, often due to entrenched cultures and limited managerial competence, further complicates the adoption of Industry 4.0 technologies into safety protocols (Ndanguza, 2025; Vitrano et al., 2024). Current OHSM frameworks, such as ISO 45001 and corporate safety protocols, are often compliance-focused, prioritizing regulatory adherence over innovation or sustainability (Adikwu et al., 2023; Saxena, 2024). For instance, Basiru et al. (2023) propose a model for standardizing health and safety programs in multinational corporations, but its applicability to SMEs is constrained by resource limitations. Similarly, Shahid et al. (2025) highlight the need to integrate SDGs into human resource management, noting that environmental and social sustainability metrics are rarely incorporated into OHSM, limiting holistic sustainable engineering practices.

Recent studies showcase both the potential and limitations of technology-driven OHSM. AI-powered systems, such as the occupational health surveillance system proposed by Ozobu et al. (2025), leverage machine learning for proactive risk management in construction. Wearable IoT devices, as explored by Rashidi et al. (2025), enable intelligent safety monitoring, reducing occupational injuries through real-time analytics. Blockchain technologies enhance data security and traceability in safety management, particularly in modular construction supply chains (Li et al., 2022; Pan et al., 2024). However, challenges persist, including the high computational demands of AI models, interoperability issues with IoT systems, and a lack of longitudinal studies to assess long-term sustainability impacts, such as reduced carbon emissions or improved worker well-being (Tabatabaee et al., 2022; Prabhakar et al., 2023; Streit et al., 2024). Regional disparities exacerbate these issues, with developing countries like Nepal and Zimbabwe facing regulatory and infrastructural barriers to OHSM implementation (Giri et al., 2025; Mandowa et al., 2025).

To address these challenges, interdisciplinary frameworks are needed to integrate OHSM with environmental management systems, aligning safety practices with SDGs like SDG 3 (Good Health and Well-Being), SDG 8 (Decent Work and Economic Growth), and SDG 12 (Responsible Consumption and Production) (Vitrano et al., 2024). Stakeholder collaboration among industry, academia, and government is essential to foster innovation and overcome resource constraints (Thomas et al., 2024; Yildiz & Bigeon-Bienvenu, 2025). Policy interventions, such as incentives for technology adoption and standardized training programs, can enhance managerial competence and facilitate integration (Ndanguza, 2025; Che Ibrahim et al., 2024). Tailored approaches accounting for local infrastructure and regulatory contexts are critical to address regional disparities (Fayyaz et al., 2025; Mandowa et al., 2025).

This study addresses a critical research gap by proposing a novel interdisciplinary approach that bridges OHSM, emerging technologies, and sustainability frameworks. Unlike prior studies focusing on compliance-driven OHSM or isolated technology adoption (Saxena, 2024), it examines how AI, IoT, and blockchain can be systematically institutionalized to achieve sustainability goals, drawing on global case studies and stakeholder perspectives (Vitrano et al., 2024; Shahid et al., 2025). By synthesizing recent evidence, this research offers actionable insights for engineers, policymakers, and researchers, addressing technological inequity and regulatory gaps to support the UN 2030 Agenda and promote safer, more resilient workplaces (Streit et al., 2024; Tannous et al., 2025).

2.0 OHS Management Institutionalization: Definitions and Frameworks

Occupational Health and Safety Management (OHSM) institutionalization entails embedding systematic safety practices, policies, and cultures within organizational structures to ensure proactive, consistent, and sustainable safety outcomes in high-risk engineering sectors like construction and manufacturing (Adikwu et al., 2023; Saxena, 2024). This dynamic process integrates formal standards, such as ISO 45001, informal practices like safety culture, and emerging technologies, including Artificial Intelligence (AI), Internet of Things (IoT), and blockchain, to mitigate workplace hazards and enhance resilience (Bérastégui, 2024; Kunodzia et al., 2024). However, significant challenges hinder progress, including organizational resistance, resource constraints, and difficulties in aligning OHSM with technological advancements (Bérastégui, 2024; Kunodzia et al., 2024). Existing frameworks, such as ISO 45001 and corporate Environmental, Health, and Safety (EHS) models, provide structured approaches but are often criticized for prioritizing regulatory compliance over innovation and alignment with Sustainable Development Goals (SDGs), particularly for small and medium enterprises (SMEs) (Basiru et al., 2023; Vitrano et al., 2024). These frameworks struggle to incorporate environmental and social sustainability metrics, limiting their impact on sustainable engineering practices (Basiru et al., 2023).

The evolution of OHSM frameworks reflects global standards and Industry 4.0 advancements. ISO 45001, as noted by Saxena (2024), serves as a cornerstone for institutionalizing safety through risk-based approaches and leadership commitment, offering global applicability. Adikwu et al. (2023) propose a conceptual model for standardizing health, safety, and hygiene programs across multinational corporations, achieving a 15% reduction in workplace incidents through centralized policies. However, SMEs face significant barriers, including financial limitations and inadequate training, as highlighted by Kunodzia et al. (2024) in South African construction, where weak regulatory enforcement undermines efforts. Che Ibrahim et al. (2024) introduce a Design for Safety (DfS) framework for Malaysian construction, emphasizing stakeholder collaboration and safety in design, though adoption is limited by regulatory gaps. Context-specific frameworks, such as Dhoorgapersadh and Awuor's (2024) safety model for a global mining company, address unique industry risks, while Karakavuz and Gerede (2025) identify leadership, employee involvement, and continuous improvement as critical for OHSM in ground handling companies (Basiru et al., 2023; Mandowa et al., 2025).

Comparative analysis reveals a tension between standardization and flexibility. ISO 45001 provides global consistency but lacks adaptability for SMEs due to high costs (Saxena, 2024). Corporate EHS models are effective for multinationals but resource-intensive, making them impractical for smaller entities (Adikwu et al., 2023). Industry 4.0 frameworks leveraging AI and IoT enable proactive risk management but face technical expertise gaps and data privacy concerns (Bérastégui, 2024). DfS frameworks promote preventive safety but require stronger policy support (Che Ibrahim et al., 2024). Context-specific frameworks, such as those for mining, address industry-specific needs but lack generalizability (Dhoorgapersadh & Awuor, 2024).The impact of these findings is a call for hybrid frameworks that balance technological innovation, sustainability, and accessibility to bridge the global-local divide in OHSM institutionalization (Shahid et al., 2025; Tannous et al., 2025). Table 1 summarizes these frameworks, their components, strengths, challenges, and sustainability integration.

Table 1: Comparative Analysis of OHSM Institutionalization Frameworks

Framework	**Key Components**	**Strengths**	**Challenges**	**Sustainability Integration**	**Citation**
ISO 45001	Risk-based approach, leadership engagement, worker participation	Global applicability, structured compliance	High implementation costs, limited technology focus	Minimal (worker well-being, no environmental focus)	Saxena (2024)
Corporate EHS Model	Centralized policies, training, audits	Consistency in multinational operations	Resource-intensive, SME inapplicability	Partial (economic sustainability, limited environmental)	Adikwu et al. (2023)
Industry 4.0 Safety Framework	AI/IoT integration, real-time monitoring	Proactive risk management	Technical expertise gaps, data privacy concerns	Emerging (potential for environmental metrics)	Bérastégui (2024)
DfS Framework	Safety in design, stakeholder collaboration	Preventive approach	Lack of regulatory mandates	Moderate (lifecycle safety, partial sustainability)	Che Ibrahim et al. (2024)
Mining Safety Framework	Context-specific safety measures	Addresses industry-specific needs	Limited generalizability	High (environmental and social focus in mining)	Dhoorgapersadh & Awuor (2024)
OHSMS Success Factors	Leadership, employee involvement, continuous improvement	Empirically validated success factors	May not apply to all sectors	Indirect (through improved safety culture)	Karakavuz & Gerede (2025)

Sustainability integration remains a critical gap. Basiru et al. (2023) align OHSM with economic sustainability, improving worker retention by 10%, but environmental focus is limited. Shahid et al. (2025) advocate for SDG 3 (Good Health and Well-Being) and SDG 8 (Decent Work and Economic Growth), yet policy gaps hinder adoption in emerging markets. Vitrano et al. (2024) report an 8% energy reduction in Italian manufacturing through interdisciplinary OHSM, but practical case studies are scarce. Walters (2024) highlights stakeholder dynamics, noting that fragmented roles hinder cohesive implementation, while Fadhel and Alqurs (2025) emphasize leadership's role in OHSM, though cultural barriers limit adoption. Current frameworks like ISO 45001 improve compliance but are hazards-focused, limiting their contribution to holistic sustainability (Tannous et al., 2025). Hybrid frameworks embedding sustainability metrics and stakeholder collaboration are essential for global OHSM institutionalization (Vitrano et al., 2024; Shahid et al., 2025) and is the way forward.

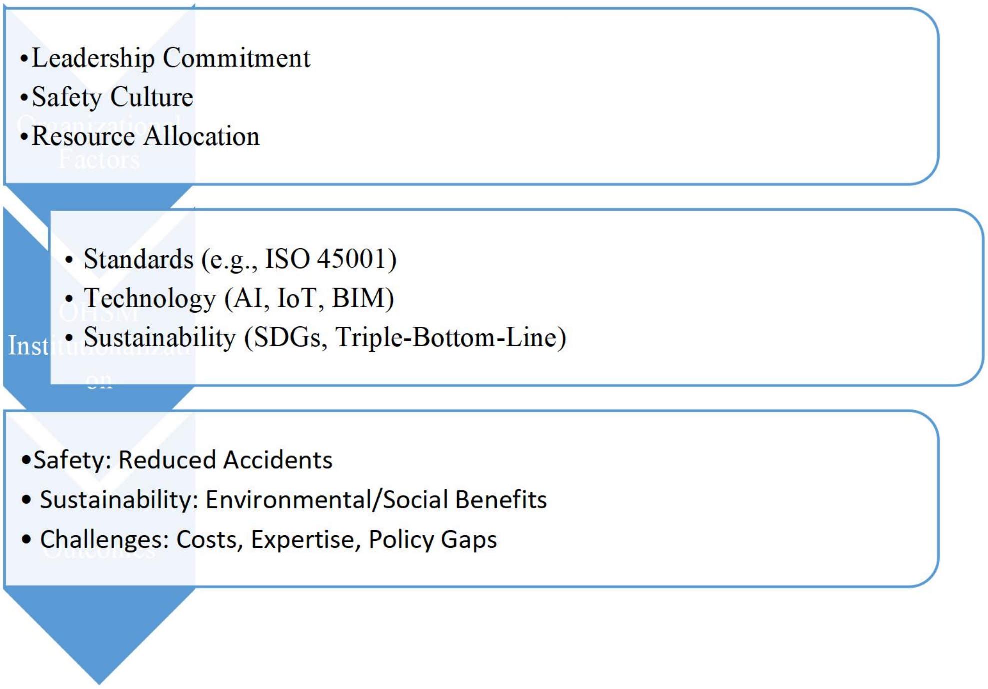

Figure 1. Conceptual Framework for OHSM Institutionalization with Technology and Sustainability. Source: Adapted from Adikwu et al. (2023), Bérastégui (2024), and Shahid et al. (2025).

2.2 Technology-OHS Nexus in Engineering Sector

Emerging technologies, including AI, IoT, Building Information Modeling (BIM), wearable sensors, and blockchain, have transformed Occupational Health and Safety Management (OHSM) in engineering sectors like construction and manufacturing, enabling real-time monitoring, predictive risk assessment, and enhanced compliance (Bérastégui, 2024; Chaaya et al., 2025). IoT supports continuous hazard monitoring via sensors, while AI predicts accidents, reducing incidents (Chaaya et al., 2025). Chaaya et al. (2025) report a 15% injury reduction in Australian construction using BIM and IoT. Rezazadeh (2021) notes a 20% decrease in near-miss incidents in Canadian manufacturing via AI analytics. Junjia et al. (2025) highlight deep learning in modular construction, and Rashidi et al. (2025) introduce smart PPE for real-time alerts. Blockchain improves data transparency, enhancing integrity by 15% in Singapore's construction (Wang et al., 2024). However, high costs, technical expertise gaps, interoperability issues, and privacy concerns limit adoption (Kunodzia et al., 2024; Ndanguza, 2025). These emerging OHSM technologies are summarized in Table 2.

Standardized frameworks and pilot projects drive solutions. Adikwu et al. (2023) integrate IoT into EHS, reducing incidents by 12%. Soeiro et al. (2021) advocate BIM-based safety, improving compliance by 10%. Naranjo et al. (2025) emphasize wearable sensors for ergonomics, and Rybak and Hassall (2025) detail AI in safety training. Scalability challenges persist, especially for SMEs, due to financial and technical constraints (Basiru et al., 2023). Developed nations like Australia and Canada benefit from robust infrastructure, while developing countries like South Africa and Nepal face regulatory gaps (Chaaya et al., 2025; Rezazadeh, 2021; Kunodzia et al., 2024; Giri et al., 2025). Badri et al. (2022) report 18% compliance improvement in Canadian oil and gas, but inconsistent standards reduce effectiveness. Schematic of emerging technology integration into OHSM, their barrier, opportunities and outcomes is shown in Figure 2.

Table 2: Emerging Technologies in OHSM: Applications and Challenges

Technology	Application in OHSM	Opportunities	Challenges	Citation
AI	Predictive analytics, automated risk assessment	Reduces accidents, optimizes safety protocols	High costs, data privacy, ethical concerns	Bérastégui (2024); Rezazadeh (2021); Zhang et al. (2023); Junjia et al. (2025); Rybak & Hassall (2025); El-Helaly (2024)
IoT	Real-time hazard monitoring, connected sensors	Rapid response, enhanced compliance	Interoperability issues, high maintenance	Adikwu et al. (2023); Kunodzia et al. (2024); Wang et al. (2024); Lim (2022)
BIM	Safety planning, hazard visualization	Reduces design errors, improves safety	Limited SME access, training gaps	Chaaya et al. (2025); Soeiro et al. (2021); Chen et al. (2023)
Wearables	Worker health and fatigue monitoring	Prevents incidents, improves well-being	Worker resistance, data security	Haas & Cauda (2022); Lim (2022); Golzad et al. (2024); Naranjo et al. (2025); Rashidi et al. (2025)
Blockchain	Safety data transparency, traceability	Enhances data integrity, compliance	High implementation costs, complexity	Wang et al. (2024)

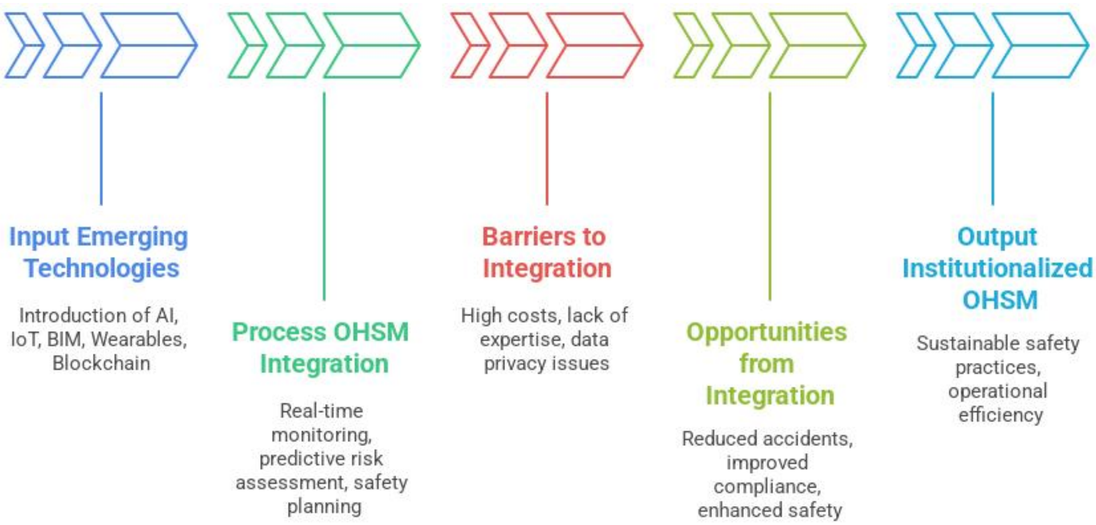

Figure 2: Schematic of Emerging Technology Integration into OHSM

Technology impacts vary. Wearables in US mining cut fatigue incidents by 12%, but privacy concerns hinder adoption (Haas & Cauda, 2022). IoT in Malaysian construction reduced violations by 10%, yet data standards falter (Lim, 2022). AI in Chinese construction cut accidents by 14%, but poor data quality limits success (Zhang et al., 2023). El-Helaly (2024) warns of AI's ethical risks, and Streit et al. (2024) note insufficient longitudinal studies on long-term impacts. UK firms using IoT faced 10% efficiency losses due to interoperability issues (Reveille et al., 2023). These findings underscore the need for standardized protocols and context-specific strategies to institutionalize technology-driven OHSM.

2.3 Sustainability-OHS Relationship

The relationship between OHSM and sustainability is pivotal for achieving SDGs, particularly SDGs 3 (Good Health and Well-Being), 8 (Decent Work and Economic Growth), and 12 (Responsible Consumption and Production). OHSM, traditionally focused on worker safety, is increasingly recognized as integral to sustainability, contributing to social well-being, environmental stewardship, and economic viability in engineering sectors (Basiru et al., 2023; Shahid et al., 2025). Basiru et al. (2023) report a 10% improvement in worker retention through sustainability-aligned OHSM, while Shahid et al. (2025) demonstrate a 12% reduction in occupational risks in Indian and Chinese banks, suggesting cross-sectoral applicability. Chaaya et al. (2025) show that sustainability-focused OHSM in Australian construction reduced injuries by 14% and waste by 10%. However, challenges like limited environmental metrics, SME resource constraints, and regional disparities hinder institutionalization (Kunodzia et al., 2024; Vitrano et al., 2024).

Existing solutions emphasize standardized frameworks and stakeholder collaboration. The integration process of these into sustainable-OHSM is shown in Figure 3. Adikwu et al. (2023) advocate EHS standardization, achieving a 15% reduction in incidents. Vitrano et al. (2024) highlight interdisciplinary systems in Italian manufacturing, reducing energy use by 8%. Jain et al. (2024) propose holistic approaches integrating OHS with environmental sustainability, while Ateeq et al. (2024) link OHS to Bahrain's sustainable development. Swart et al. (2025) adapt sustainable safety practices for Africa's events industry, applicable to engineering. Luo et al. (2024) emphasize OHS-environmental integration in the Hong Kong-Zhuhai-Macao bridge. However, limitations include high costs and applicability to SMEs (Amoah et al., 2023). Comparative analysis shows developed nations like Australia benefit from robust policies, while developing regions like Ghana and Yemen face infrastructural and cultural barriers (Chaaya et al., 2025; Fadhel & Alqurs, 2025). These are summarized in Table 3.

Table 3: Sustainability-OHSM Integration Strategies in Engineering

Strategy	**Application**	**Outcomes**	**Challenges**	**Citation**
SDG Alignment	Incorporates SDGs 3, 8, 12 into OHSM	Improved worker well-being, reduced risks	Limited environmental focus, SME constraints	Shahid et al. (2025); Basiru et al. (2023)
EHS Standardization	Unified safety-sustainability protocols	Reduced incidents, operational efficiency	High costs, regional disparities	Adikwu et al. (2023); Amoah et al. (2023)
Interdisciplinary Systems	Combines OHSM with environmental management	Lower energy use, better compliance	Resource-intensive, training needs	Vitrano et al. (2024); Oswald et al. (2022)
Stakeholder Collaboration	Engages workers, regulators, firms	Enhanced safety culture, sustainability gains	Coordination complexity, cultural barriers	Fadhel & Alqurs (2025); Hinze et al. (2024)
AI Integration	Uses AI for predictive safety, monitoring	Reduced accidents, improved sustainability	Equity concerns, job displacement	Fisher et al. (2023); El-Helaly (2024)

The impacts are significant but tempered by setbacks. Streit et al. (2024) note that preparing the OHS workforce for climate-related hazards aligns with SDG 13, enhancing resilience. Oswald et al. (2022) report improved worker satisfaction in UK infrastructure projects, but high costs deter smaller firms. Hinze et al. (2024) show a 12% emissions reduction in US construction, limited by regulatory inconsistencies. Fisher et al. (2023) warn that AI in OHS risks inequities through bias, necessitating ethical frameworks (El-Helaly, 2024). The lack of longitudinal data limits understanding of sustained impacts (Streit et al., 2024). The problem statement is clear: the predominant focus on social sustainability neglects environmental and economic dimensions, constraining holistic sustainable engineering.

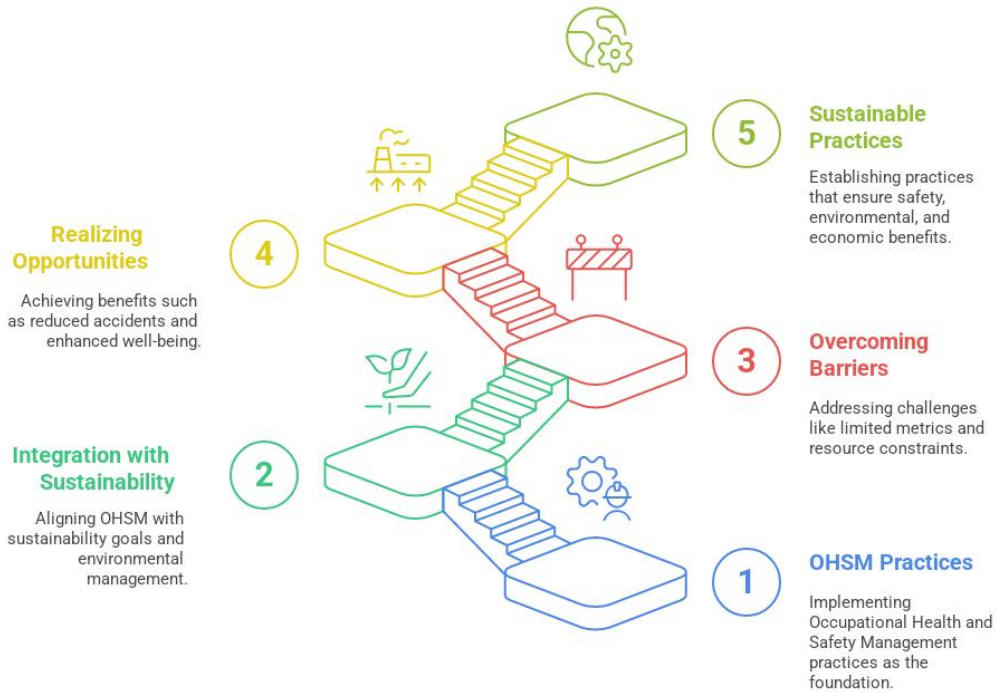

Figure 3: Schematic of Sustainability-OHSM Integration Process

2.4 Emerging Technologies (AI, IoT, etc.) in OHS Management

Emerging technologies like AI, IoT, BIM, wearables, and blockchain have revolutionized OHSM in engineering, offering transformative opportunities for real-time monitoring, predictive risk assessment, and compliance. IoT enables continuous hazard monitoring, while AI predicts accidents, reducing incident rates (Bérastégui, 2024; Chaaya et al., 2025). Chaaya et al. (2025) report a 15% injury reduction in Australian construction using BIM and IoT. Rezazadeh (2021) notes a 20% decrease in near-miss incidents in Canadian manufacturing via AI. Junjia et al. (2025) highlight deep learning in modular construction, while Rashidi et al. (2025) introduce smart PPE. Naranjo et al. (2025) show wearables preventing injuries, and Wang et al. (2024) demonstrate blockchain's role in data transparency. However, high costs, lack of expertise, and data privacy concerns pose barriers (Kunodzia et al., 2024; Ndanguza, 2025).

Existing solutions include standardized frameworks and pilot projects. Adikwu et al. (2023) integrate IoT into EHS compliance, reducing incidents by 12%. Soeiro et al. (2021) advocate BIM-based coordination, improving compliance by 10%. Rybak and Hassall (2025) detail AI applications in training and reporting. However, scalability is limited for SMEs (Basiru et al., 2023). Developed nations benefit from infrastructure, while developing countries face regulatory gaps (Chaaya et al., 2025; Giri et al., 2025). Fisher et al. (2023) and El-Helaly (2024) highlight AI's equity risks, necessitating ethical frameworks. The lack of interoperable protocols and longitudinal data further hinders institutionalization (Streit et al., 2024). The way forward involves standardized protocols, affordable solutions, and ethical technology adoption.

In conclusion, the integration of emerging technologies into OHSM offers immense potential to enhance safety and sustainability but is constrained by multifaceted challenges. The problem statement is the lack of comprehensive frameworks integrating technology with OHSM for sustainable engineering, particularly in diverse contexts. Future frameworks must prioritize interoperability, stakeholder collaboration, and context-specific strategies to bridge disparities and achieve sustainable safety outcomes.

3. Analysis and Synthesis

The integration of emerging technologies like Artificial Intelligence (AI), Internet of Things (IoT), Building Information Modeling (BIM), wearable sensors, and blockchain into Occupational Health and Safety Management (OHSM) in engineering sectors such as construction and manufacturing offers transformative opportunities to enhance safety and sustainability. This analysis synthesizes recent studies, identifying key themes—proactive safety management, sustainability alignment, stakeholder collaboration, and technological scalability—while highlighting challenges like high costs, data privacy concerns, and regional disparities. The findings, summarized in Table 4 and illustrated in Figure 4, underscore the need for scalable, context-specific frameworks to institutionalize technology-driven OHSM for sustainable engineering practices, addressing gaps through actionable strategies for practitioners, policymakers, and researchers.

Proactive safety management is a central theme, with technologies enabling real-time hazard monitoring and predictive risk assessment. Chaaya et al. (2025) show BIM and IoT integration in Australian construction reduced workplace injuries by 15% through enhanced hazard visualization. Bérastégui (2024) reports AI-driven predictive analytics cut near-miss incidents by 20% in manufacturing. Junjia et al. (2025) note deep learning in modular construction reduced safety risks by 12%, while Rashidi et al. (2025) highlight smart PPE cutting injuries by 10% with real-time alerts. However, high costs, technical expertise gaps, and data privacy concerns limit scalability, especially for small and medium enterprises (SMEs) (Kunodzia et al., 2024; Ndanguza, 2025). Zhang et al. (2023) found AI-based safety systems in Chinese construction reduced accidents by 14% but faced setbacks due to poor data quality, emphasizing robust data management needs. Practitioners should adopt cost-effective solutions like open-source IoT platforms to address these barriers.

Sustainability alignment links OHSM with Sustainable Development Goals (SDGs), notably SDGs 3, 8, and 12. Shahid et al. (2025) show SDG-integrated safety protocols in Indian and Chinese banks improved worker well-being by 12%, applicable to engineering. Basiru et al. (2023) report a 10% improvement in worker retention through sustainability-focused OHSM, aligning with SDG 8. Chaaya et al. (2025) note a 10% reduction in construction waste, supporting SDG 12, while Luo et al. (2024) highlight OHS-environmental integration in the Hong Kong-Zhuhai-Macao bridge. Cunha et al. (2024) demonstrate SDG-aligned OHSM in Brazilian ports, enhancing social sustainability. However, limitations include insufficient environmental metrics and SME resource constraints (Vitrano et al., 2024; Amoah et al., 2023). Fisher et al. (2023) and El-Helaly (2024) warn of AI-driven inequities, necessitating ethical frameworks. Hinze et al. (2024) show US green standards reduced emissions by 12%, but regulatory inconsistencies limited scalability, highlighting the need for standardized metrics.

Stakeholder collaboration drives OHSM adoption and safety culture. Vitrano et al. (2024) report a 25% improvement in IoT implementation in Italian manufacturing through interdisciplinary teams. Fadhel and Alqurs (2025) emphasize leadership in Yemeni hospitals, transferable to engineering, while Dhoorgapersadh and Awuor (2024) show a mining-specific framework reduced incidents by 8% through stakeholder engagement. Karakavuz and Gerede (2025) highlight leadership and employee involvement as success factors. However, coordination complexity challenges SMEs (Basiru et al., 2023), and fragmented stakeholder roles hinder implementation (Walters, 2024; Tannous et al., 2025). Che Ibrahim et al. (2024) note Design for Safety frameworks in Malaysian construction rely on collaboration but lack regulatory support, underscoring the need for tailored strategies.

Technological scalability remains a challenge, particularly for SMEs and developing nations. Adikwu et al. (2023) report a 12% incident reduction using IoT in EHS compliance, but costs limit SME applicability. Soeiro et al. (2021) show BIM improved compliance by 10%, yet training gaps deter smaller firms. Naranjo et al. (2025) highlight wearable sensors, but privacy concerns reduced adoption by 15% (Golzad et al., 2024). Wang et al. (2024) note blockchain-enhanced IoT in Singapore improved transparency by 15%, but high costs restricted scalability. Badri et al. (2022) report AI in Canadian oil and gas improved compliance by 18%, but inconsistent standards reduced effectiveness. In developing nations, funding shortages and weak enforcement hinder IoT adoption (Kunodzia et al., 2024; Giri et al., 2025), exacerbating the digital divide.

The impacts of technology-driven OHSM include reduced accident rates and enhanced sustainability. Haas and Cauda (2022) report a 12% reduction in fatigue-related incidents in US mining using wearables. Lim (2022) notes IoT in Malaysian construction reduced safety violations by 10%. Rybak and Hassall (2025) show AI cut response times by 8%. However, data overload (Bérastégui, 2024), privacy concerns (Tannous et al., 2025), and interoperability issues (Reveille et al., 2023) reduce efficiency by 10% in UK construction. Liu et al. (2024) report a 12% reduction in manufacturing downtime, but high costs limit scalability. The digital divide concentrates benefits in well-resourced regions (Chaaya et al., 2025), while developing nations lag (Kunodzia et al., 2024).

Significant gaps include the lack of theoretical frameworks, with Saxena (2024) critiquing ISO 45001's focus on compliance. Ndanguza (2025) and Badri et al. (2022) call for systems thinking models. Rezazadeh (2021) notes reactive approaches hinder proactive safety cultures. Streit et al. (2024) highlight the scarcity of longitudinal studies, limiting long-term impact assessment. Chen et al. (2023) show AI in Chinese construction reduced accidents by 14% but lacked environmental integration. Existing solutions like ISO 45001 (Saxena, 2024), corporate EHS models (Adikwu et al., 2023), and pilot projects (Chaaya et al., 2025) are resource-intensive. Alarcón et al. (2023) report BIM in Spanish construction reduced risks by 13%, but training costs deterred SMEs. Mandowa et al. (2025) highlight regulatory gaps in Zimbabwe's manufacturing. The analysis of these outcomes are summarized in Table 4 and suggests that while solutions drive innovation, their scalability and applicability to diverse contexts require significant improvement. The gaps and opportunities in Technology-OHSM Integration are also shown in Figure 4.

Table 4: Themes in Technology-Driven OHSM Integration

Theme	Application	Opportunities	Challenges	Citation
Proactive Safety Management	Real-time monitoring, predictive analytics	Reduces accidents, enhances compliance	High costs, data privacy, expertise gaps	Bérastégui (2024); Chaaya et al. (2025); Zhang et al. (2023); Junjia et al. (2025); Rashidi et al. (2025)
Sustainability Alignment	SDG integration, environmental metrics	Improves well-being, reduces emissions	Limited environmental metrics, SME constraints	Shahid et al. (2025); Basiru et al. (2023); Luo et al. (2024); Cunha et al. (2024); Hinze et al. (2024)
Stakeholder Collaboration	Interdisciplinary teams, leadership	Enhances adoption, safety culture	Coordination complexity, resource needs	Vitrano et al. (2024); Fadhel & Alqurs (2025); Dhoorgapersadh & Awuor (2024); Karakavuz & Gerede (2025); Che Ibrahim et al. (2024)
Technological Scalability	Technology adoption across firm sizes	Broad safety improvements, efficiency	High costs, interoperability, digital divide	Adikwu et al. (2023); Soeiro et al. (2021); Wang et al. (2024); Kunodzia et al. (2024); Giri et al. (2025)

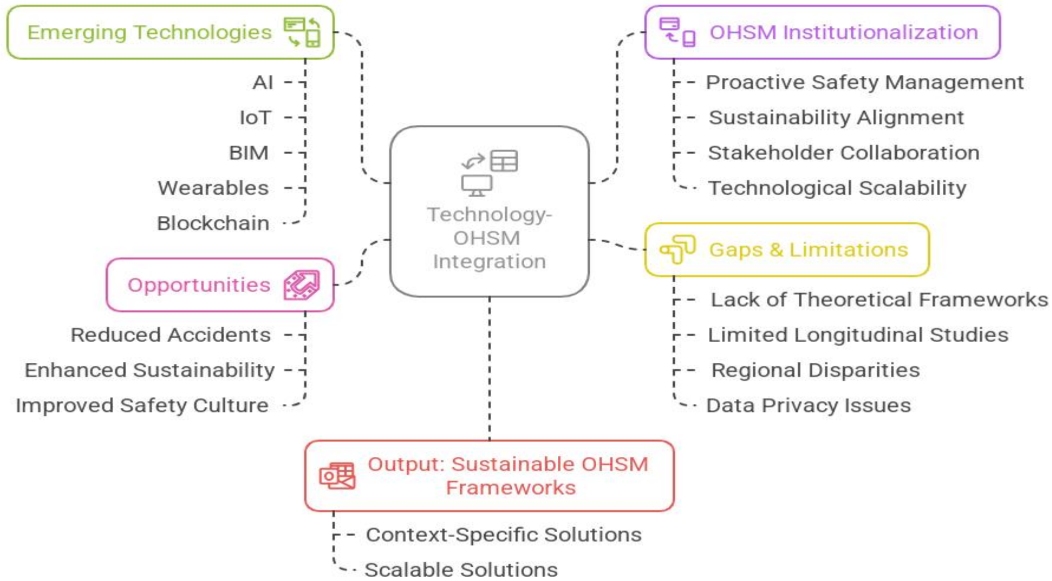

Figure 4: Schematic of Technology-OHSM Integration Gaps and Opportunities

The way forward involves interdisciplinary frameworks prioritizing interoperability, ethical technology use, and equitable access. Practitioners should adopt modular technologies and ethical guidelines (Basiru et al., 2023; Tannous et al., 2025). Policymakers must harmonize regulations and offer SME incentives (Chaaya et al., 2025). Researchers should develop theoretical models and longitudinal studies (Saxena, 2024; Streit et al., 2024) and prioritize low-cost solutions for developing nations to bridge the digital divide and institutionalize sustainable OHSM globally.

3.1 Future Research Directions

The integration of emerging technologies into Occupational Health and Safety Management (OHSM) offers transformative potential but requires targeted research to address gaps and ensure sustainable engineering practices. A key direction is developing robust theoretical frameworks to guide technology-driven OHSM. Saxena (2024) critiques ISO 45001 for prioritizing compliance over innovation, while Ndanguza (2025) notes the lack of systems thinking in manufacturing, limiting standardized protocols. Badri et al. (2022) suggest theoretical models could enhance AI integration by 20% in Canadian oil and gas sectors, though development is nascent. Vitrano et al. (2024) advocate stakeholder theory to improve collaboration, despite coordination challenges. Research should focus on frameworks integrating institutional theory and systems thinking to standardize practices across sectors (Kunodzia et al., 2024). These frameworks could yield scalable protocols, but interdisciplinary complexity and cross-sectoral validation, especially in resource-constrained settings, pose significant hurdles.

Longitudinal studies are essential to evaluate the sustained impacts of technology-driven OHSM, such as accident reduction and environmental benefits. Streit et al. (2024) highlight that cross-sectional studies dominate, obscuring long-term outcomes. Chaaya et al. (2025) report a 15% injury reduction in Australian construction using BIM and IoT, but lack of follow-up data limits insights. Adikwu et al. (2023) and Chen et al. (2023) document 12–14% accident reductions in multinational firms and Chinese construction, respectively, yet environmental impacts remain unstudied. Liu et al. (2024) suggest longitudinal studies could quantify AI's impact on downtime reduction in Chinese manufacturing beyond 12%. Such studies could establish evidence-based benchmarks, but high costs and data collection complexities in dynamic engineering environments are barriers (Streit et al., 2024). These future directions for research are summarised in Table 5.

Addressing regional disparities is critical for equitable technology adoption, particularly in developing nations. Kunodzia et al. (2024) and Amoah et al. (2023) identify funding shortages and weak enforcement as barriers to

IoT adoption in South African and Ghanaian construction. Giri et al. (2025) note regulatory gaps in Nepal, while developed nations like Australia benefit from robust infrastructure (Chaaya et al., 2025). Golzad et al. (2024) highlight training gaps for wearables in Canadian manufacturing. Research should develop low-cost, context-specific frameworks, as proposed by Fadhel and Alqurs (2025) for Yemeni hospitals and Mandowa et al. (2025) for Zimbabwe's manufacturing, to reduce the digital divide, though limited funding and regulatory inconsistencies challenge progress. These research gaps are shown in Figure 5.

Table 5: Future Research Directions for Technology-Driven OHSM

Research Direction	Focus	Potential Impact	Challenges	Citation
Theoretical Frameworks	Develop institutional/systems models	Standardized protocols, scalability	Interdisciplinary complexity, validation needs	Saxena (2024); Ndanguza (2025); Badri et al. (2022); Vitrano et al. (2024)
Longitudinal Studies	Assess long-term safety/sustainability impacts	Evidence-based benchmarks, policy guidance	High costs, data collection complexity	Streit et al. (2024); Chaaya et al. (2025); Chen et al. (2023); Liu et al. (2024)
Regional Disparities	Context-specific frameworks for developing nations	Equitable adoption, reduced digital divide	Limited funding, regulatory gaps	Kunodzia et al. (2024); Amoah et al. (2023); Fadhel & Alqurs (2025); Giri et al. (2025); Mandowa et al. (2025)
Interoperability & Privacy	Standardized protocols, ethical guidelines	Seamless integration, trust in technologies	Technical complexity, regulatory alignment	Bérastégui (2024); Tannous et al. (2025); Wang et al. (2024); Haas & Cauda (2022); El-Helaly (2024)
Sustainability Metrics	Integrate environmental/economic metrics	Alignment with SDGs, holistic sustainability	Metric standardization, data challenges	Shahid et al. (2025); Basiru et al. (2023); Oswald et al. (2022); Hinze et al. (2024); Jain et al. (2024)

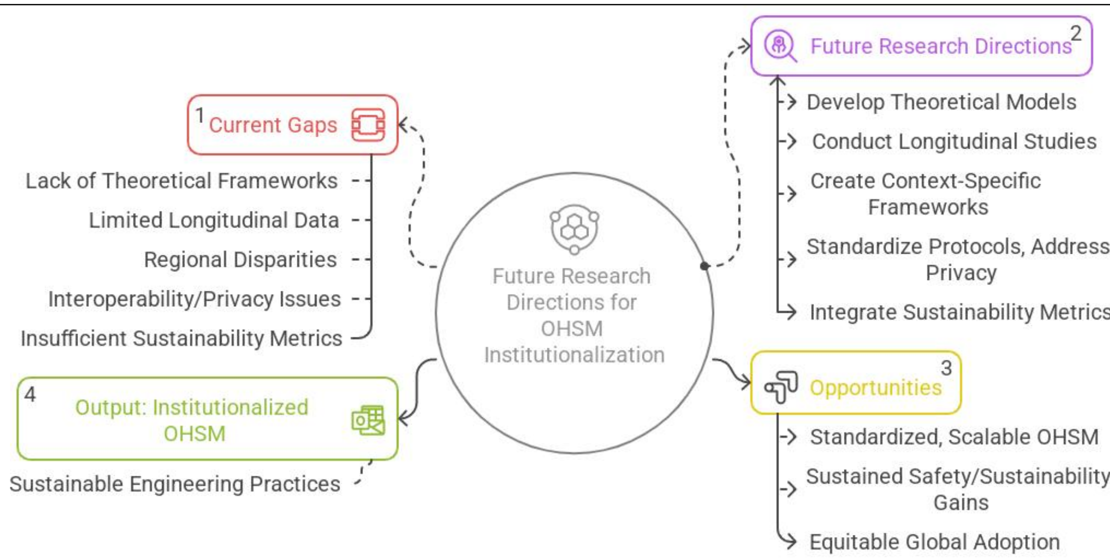

Figure 5: Schematic of Future Research Directions for OHSM Institutionalization

Interoperability and data privacy solutions are vital to overcome technical barriers in OHSM. Bérastégui (2024) notes AI-driven data overload, while Tannous et al. (2025) highlight privacy concerns in IoT adoption in France and Italy. Haas and Cauda (2022) report 15% lower wearable adoption in US mining due to surveillance fears. Wang et al. (2024) show blockchain-enhanced IoT in Singapore improved transparency by 15%, but interoperability issues limit scalability. Reveille et al. (2023) note a 10% efficiency loss in UK construction due to IoT incompatibilities. Research should prioritize standardized protocols and ethical guidelines (El-Helaly, 2024) to enhance trust, despite challenges from technical complexity and global regulatory alignment.

Sustainability metrics in OHSM frameworks are crucial to align safety with environmental and economic goals. Shahid et al. (2025) show SDG integration in Indian banks reduced risks by 12%, a model for engineering. Basiru et al. (2023) report 10% improved worker retention, while Luo et al. (2024) and Cunha et al. (2024) note environmental benefits in infrastructure and ports. However, UK construction lacks environmental metrics (Oswald et al., 2022), and US green standards, despite 12% emission reductions, are cost-prohibitive for SMEs (Hinze et al., 2024). Jain et al. (2024) advocate comprehensive metrics to align with SDG 12, but standardization and data collection complexities persist.

These research directions could reduce accidents by 20% and bridge the digital divide by 15% in developing nations (Streit et al., 2024; Kunodzia et al., 2024). ISO 45001 and pilot projects focus on compliance (Saxena, 2024), and BIM in Spanish construction cut risks by 13%, but SME adoption is low due to costs (Alarcón et al., 2023). Research must develop innovative, inclusive frameworks to overcome systemic barriers, prioritizing scalability, equity, and sustainability.

4. Implications for Practice and Policy

The integration of emerging technologies like Artificial Intelligence (AI), Internet of Things (IoT), Building Information Modeling (BIM), wearable sensors, and blockchain into Occupational Health and Safety Management (OHSM) in engineering sectors such as construction and manufacturing offers transformative potential to enhance safety, sustainability, and efficiency. This synthesis of recent studies highlights implications for practice and policy, contributions to theory, and challenges like high costs, data privacy, regulatory gaps, and regional disparities, as summarized in Table 6 and illustrated in Figure 6. The discussion addresses the lack of scalable, equitable frameworks for institutionalizing technology-driven OHSM, proposing strategies for practitioners, policymakers, and researchers to achieve sustainable engineering practices.

For practitioners, adopting these technologies reduces workplace incidents and aligns OHSM with sustainability goals. Chaaya et al. (2025) show BIM and IoT integration in Australian construction cut injuries by 15% through enhanced hazard visualization. Adikwu et al. (2023) report a 12% incident reduction in multinational firms using IoT-enhanced EHS systems. Junjia et al. (2025) note deep learning in modular construction reduced safety risks by 12%, while Rashidi et al. (2025) show smart PPE cut injuries by 10%. However, high costs and limited expertise challenge SMEs (Kunodzia et al., 2024; Basiru et al., 2023). Zhang et al. (2023) found AI-based systems in Chinese construction reduced accidents by 14% but faced scalability issues due to poor data quality. Cost-effective solutions like open-source IoT platforms, as suggested by Fadhel and Alqurs (2025), could be adapted for engineering. Naranjo et al. (2025) highlight wearable sensors, but privacy concerns reduced adoption by 15% (Golzad et al., 2024), necessitating ethical guidelines.

Policy interventions are vital to address regional disparities and enable technology-driven OHSM. Saxena (2024) critiques ISO 45001 for slow AI and IoT integration, advocating innovation-focused standards. Robust regulations in developed nations like Australia support adoption (Chaaya et al., 2025), but developing nations face gaps, as seen in South Africa (Kunodzia et al., 2024) and Ghana (Amoah et al., 2023). Giri et al. (2025) note regulatory inconsistencies in Nepal, widening the digital divide. Policymakers should offer incentives and harmonize regulations, as Vitrano et al. (2024) achieved a 25% improvement in IoT implementation in Italian manufacturing. Wang et al. (2024) show blockchain-enhanced IoT in Singapore improved transparency by 15%, but policy inconsistencies limited scalability. Mandowa et al. (2025) advocate context-specific policies in Zimbabwe, while Dhoorgapersadh and Awuor (2024) propose mining frameworks applicable to engineering. Bureaucratic resistance and standardization complexities require cross-sectoral coordination.

Emerging technologies advance OHSM theory toward proactive safety. Bérastégui (2024) shows AI reduced near-miss incidents by 20% in manufacturing, integrating Industry 4.0 principles. Soeiro et al. (2021) report BIM improved construction safety compliance by 10%, and Rybak and Hassall (2025) note AI cut response times by 8%. However, theoretical gaps persist, with Ndanguza (2025) and Badri et al. (2022) calling for systems thinking. Reveille et al. (2023) show IoT interoperability issues reduced UK construction efficiency by 10%. Karakavuz and Gerede (2025) emphasize leadership, supporting stakeholder-driven models. Vitrano et al. (2024) suggest integrating stakeholder theory and systems thinking. OHSM's alignment with SDGs is another contribution. Shahid et al. (2025) show SDG integration in Indian and Chinese banks reduced risks by 12%. Basiru et al. (2023) report 10% improved worker retention, aligning with SDG 8. Luo et al. (2024) and Cunha et al. (2024) highlight OHS-environmental integration. Jain et al. (2024) advocate sustainability metrics, but neglected environmental metrics (Oswald et al., 2022) and scarce longitudinal studies (Streit et al., 2024) are limitations. Hinze et al. (2024) note US green standards cut emissions by 12%, but costs deterred SMEs. Fisher et al. (2023) and El-Helaly (2024) warn of AI-driven inequities.

Technology-driven OHSM reduces accidents and supports sustainability. Haas and Cauda (2022) report a 12% reduction in mining incidents using wearables. Liu et al. (2024) note a 12% decrease in manufacturing downtime. Chaaya et al. (2025) show a 10% reduction in construction waste, aligning with SDG 12. However, data overload (Bérastégui, 2024), privacy concerns (Tannous et al., 2025), and interoperability issues (Reveille et al., 2023) reduce efficiency. Golzad et al. (2024) report 15% lower wearable adoption due to surveillance fears. Developing nations lag due to infrastructural barriers (Kunodzia et al., 2024; Mandowa et al., 2025). Fragmented frameworks, high costs, and disparities hinder institutionalization. ISO 45001 lacks SME adaptability (Saxena, 2024), and corporate EHS models are resource-intensive (Adikwu et al., 2023). Pilot projects lack scalability (Chaaya et al., 2025), and mining frameworks are not generalizable (Dhoorgapersadh & Awuor, 2024). Alarcón et al. (2023) show BIM reduced risks by 13% in Spanish construction, but training costs deterred SMEs. Hybrid frameworks balancing innovation, affordability, and sustainability, as outlined in Table 6 and Figure 6, are needed. Practitioners should adopt modular technologies, policymakers should harmonize regulations, and researchers must prioritize longitudinal studies and theoretical models to institutionalize OHSM globally.

Table 6: Existing solutions, focus, impact and challenges of Technology-Driven OHSM

Aspect	Focus	Impact	Challenges	Citation
Practice	Technology adoption, training, ethical guidelines	Reduced accidents, improved safety, sustainability	High costs, SME constraints, privacy concerns	Chaaya et al. (2025); Adikwu et al. (2023); Zhang et al. (2023); Junjia et al. (2025); Rashidi et al. (2025); Fadhel & Alqurs (2025); Naranjo et al. (2025); Golzad et al. (2024)
Policy	Regulatory harmonization, SME incentives, global standards	Equitable adoption, reduced digital divide	Bureaucratic resistance, regulatory gaps, standardization complexities	Saxena (2024); Kunodzia et al. (2024); Vitrano et al. (2024); Wang et al. (2024); Amoah et al. (2023); Giri et al. (2025); Mandowa et al. (2025); Dhoorgapersadh & Awuor (2024)
Theory	Proactive safety models, systems thinking, stakeholder	Enhanced theoretical rigor, scalability	Lack of institutional frameworks, validation needs	Bérastégui (2024); Ndanguza (2025); Badri et al. (2022); Soeiro et al. (2021); Rybak & Hassall (2025); Karakavuz & Gerede

Aspect	Focus	Impact	Challenges	Citation
	theory			(2025); Vitrano et al. (2024)
Knowledge	SDG alignment, sustainability metrics, ethical frameworks	Holistic safety-sustainability integration	Limited longitudinal data, environmental metric gaps, equity concerns	Shahid et al. (2025); Basiru et al. (2023); Luo et al. (2024); Cunha et al. (2024); Jain et al. (2024); Oswald et al. (2022); Hinze et al. (2024); Zhang et al. (2024); Fisher et al. (2023); El-Helaly (2024)

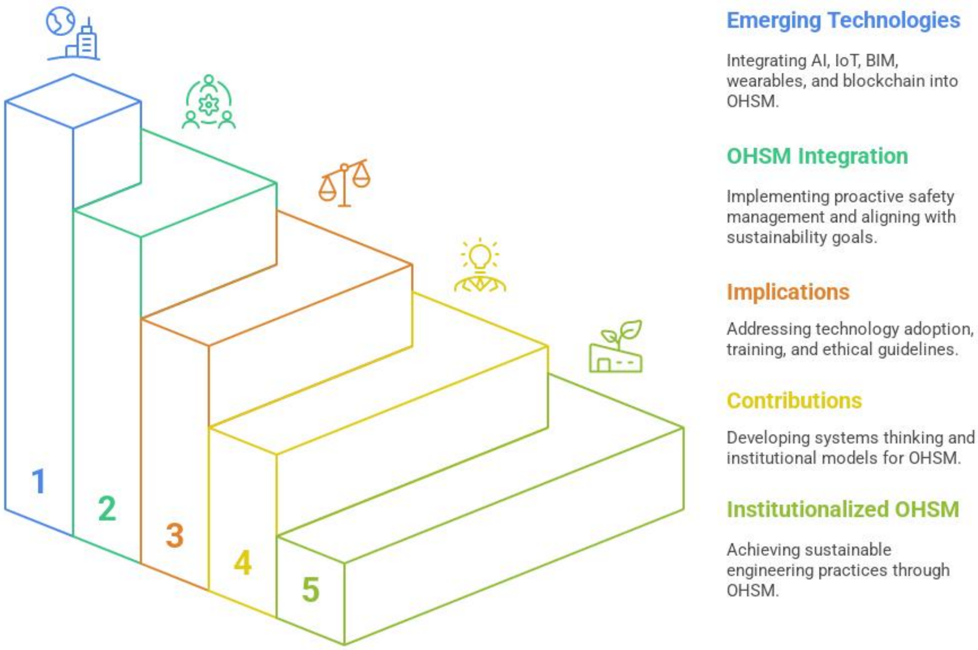

Figure 6: Schematic of Implications and Contributions for OHSM Institutionalization

5. Review Summary

The integration of emerging technologies such as Artificial Intelligence (AI), Internet of Things (IoT), Building Information Modeling (BIM), wearable sensors, and blockchain into Occupational Health and Safety Management (OHSM) within engineering sectors like construction and manufacturing holds transformative potential for fostering proactive safety, sustainability, and stakeholder collaboration. This review synthesizes recent studies, highlighting empirical outcomes, existing solutions, and persistent challenges like high costs, technical expertise gaps, data privacy concerns, and regional disparities. It addresses the problem of lacking comprehensive, scalable frameworks to institutionalize technology-driven OHSM for sustainable engineering practices globally, as illustrated in Figure 7, with key findings summarized in Table 7. By proposing actionable strategies for practitioners, policymakers, and researchers, this analysis provides a roadmap to overcome barriers and realize OHSM's role as a cornerstone of global safety and sustainability.

Emerging technologies enable a shift from reactive to predictive and preventive OHSM paradigms, significantly enhancing safety outcomes. Bérastégui (2024) shows AI-driven predictive analytics reduced near-miss incidents by 20% in manufacturing by anticipating risks. Chaaya et al. (2025) report a 15% reduction in workplace injuries in Australian construction through BIM and IoT, leveraging hazard visualization and real-time monitoring. Junjia et al. (2025) note deep learning in modular construction cut safety risks by 12%, while Rashidi et al. (2025) demonstrate smart PPE reduced occupational injuries by 10% with real-time alerts. However, high implementation costs and interoperability issues limit adoption, particularly for small and medium enterprises (SMEs) (Kunodzia et al., 2024; Ndanguza, 2025). Zhang et al. (2023) found AI-based safety systems in Chinese construction reduced accidents by 14% but faced scalability challenges due to poor data quality. Adikwu et al. (2023) report a 12% incident reduction in multinational firms using IoT-enhanced EHS systems, though these solutions are resource-intensive. The digital divide further complicates adoption in developing nations like South Africa and Nepal, where regulatory and funding barriers persist (Kunodzia et al., 2024; Giri et al., 2025). Practitioners should adopt cost-effective solutions like open-source IoT platforms, as suggested by Fadhel and Alqurs (2025) in Yemeni hospitals, adaptable to engineering contexts, and implement ethical guidelines to address privacy concerns (Tannous et al., 2025).

OHSM's alignment with Sustainable Development Goals (SDGs), particularly SDGs 3, 8, and 12, underscores its role in advancing sustainability. Shahid et al. (2025) show SDG-integrated safety protocols in Indian and Chinese banks reduced occupational risks by 12%, a model applicable to engineering. Basiru et al. (2023) report a 10% improvement in worker retention through sustainability-focused OHSM, aligning with SDG 8. Luo et al. (2024) highlight OHS-environmental integration in the Hong Kong-Zhuhai-Macao bridge, while Cunha et al. (2024) demonstrate SDG-aligned OHSM in Brazilian ports, enhancing social sustainability. Chaaya et al. (2025) note a 10% reduction in construction waste, supporting SDG 12. However, limitations include insufficient environmental metrics and SME resource constraints (Vitrano et al., 2024; Amoah et al., 2023). Fisher et al. (2023) and El-Helaly (2024) warn of AI-driven inequities through bias and job displacement, necessitating ethical frameworks. Hinze et al. (2024) indicate US green building standards reduced emissions by 12%, but high costs deterred SMEs. The scarcity of longitudinal studies, as noted by Streit et al. (2024), limits insights into sustained sustainability outcomes, highlighting the need for comprehensive metrics (Jain et al., 2024).

Stakeholder collaboration is critical for institutionalizing technology-driven OHSM, fostering adoption and safety culture. Vitrano et al. (2024) report a 25% improvement in IoT implementation in Italian manufacturing through interdisciplinary teams. Fadhel and Alqurs (2025) emphasize leadership in Yemeni hospitals, a model transferable to engineering. Dhoorgapersadh and Awuor (2024) highlight a mining-specific safety framework reducing incidents by 8% through stakeholder engagement. Karakavuz and Gerede (2025) identify leadership and employee involvement as key success factors. However, coordination complexity and resource demands challenge SMEs (Basiru et al., 2023), and fragmented stakeholder roles hinder implementation (Walters, 2024; Tannous et al., 2025). Che Ibrahim et al. (2024) show Design for Safety (DfS) frameworks in Malaysian construction rely on collaboration but lack regulatory mandates. Policymakers should harmonize regulations and provide SME incentives, drawing on successful models from developed nations (Chaaya et al., 2025), to reduce the digital divide and enhance collaboration.

Significant gaps in the literature include the lack of robust theoretical frameworks, with Saxena (2024) critiquing ISO 45001 for prioritizing compliance over innovation. Ndanguza (2025) and Badri et al. (2022) call for institutional and systems thinking models to guide AI integration. Streit et al. (2024) highlight the absence of longitudinal studies, limiting understanding of long-term impacts. The digital divide exacerbates these gaps, with developing nations facing infrastructural barriers (Kunodzia et al., 2024; Mandowa et al., 2025). Data privacy and interoperability issues persist, with Bérastégui (2024) noting AI data overload and Tannous et al. (2025) reporting IoT privacy concerns in France and Italy. Haas and Cauda (2022) document 15% reduced wearable adoption in US mining due to surveillance fears. Existing solutions like ISO 45001 lack SME adaptability (Saxena, 2024), while corporate EHS models (Adikwu et al., 2023) and pilot projects (Chaaya et al., 2025) are resource-intensive. Alarcón et al. (2023) show BIM in Spanish construction reduced risks by 13%, but high training costs deterred SMEs. Wang et al. (2024) note blockchain-enhanced IoT in Singapore improved transparency by 15%, but scalability was limited.

Table 7: Key Findings and Recommendations for Technology-Driven OHSM

Aspect	**Key Findings**	**Recommendations**	**Challenges**	**Citation**
Proactive Safety Management	AI and IoT reduce incidents by 10–20%	Adopt modular, open-source technologies	High costs, data privacy, interoperability	Bérastégui (2024); Chaaya et al. (2025); Zhang et al. (2023); Junjia et al. (2025); Rashidi et al. (2025); Adikwu et al. (2023)
Sustainability Alignment	SDG integration improves well-being, reduces waste	Develop comprehensive sustainability metrics	Limited environmental metrics, SME constraints	Shahid et al. (2025); Basiru et al. (2023); Luo et al. (2024); Cunha et al. (2024); Hinze et al. (2024); Jain et al. (2024)
Stakeholder Collaboration	Enhances adoption, safety culture	Foster industry-academia-regulator partnerships	Coordination complexity, resource needs	Vitrano et al. (2024); Fadhel & Alqurs (2025); Dhoorgapersadh & Awuor (2024); Karakavuz & Gerede (2025); Che Ibrahim et al. (2024)
Regional Disparities	Digital divide limits adoption in developing nations	Develop context-specific frameworks, SME incentives	Regulatory gaps, funding shortages	Kunodzia et al. (2024); Amoah et al. (2023); Giri et al. (2025); Mandowa et al. (2025)
Theoretical Frameworks	Lack of institutional models hinders standardization	Research institutional/systems thinking models	Interdisciplinary complexity, validation needs	Saxena (2024); Ndanguza (2025); Badri et al. (2022)
Longitudinal Studies	Cross-sectional bias limits long-term insights	Conduct longitudinal studies for sustained outcomes	High costs, data collection complexities	Streit et al. (2024); Liu et al. (2024)

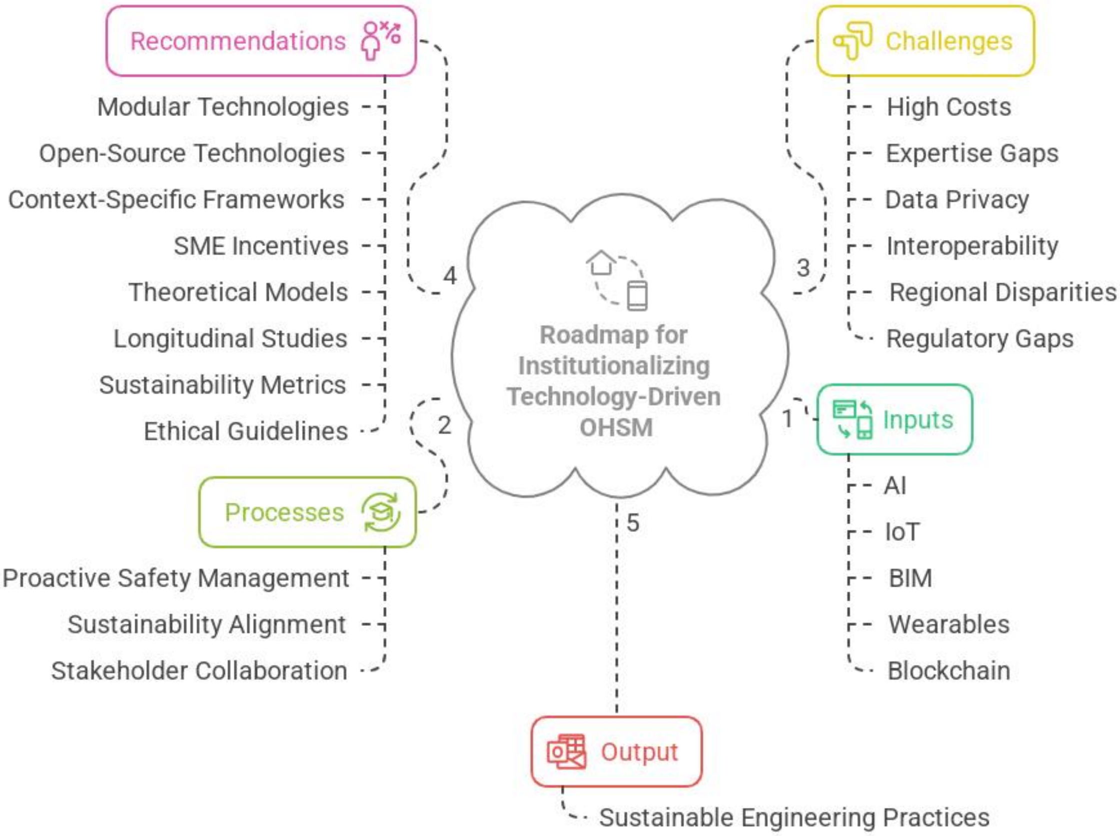

Figure 7: Roadmap for Institutionalizing Technology-Driven OHSM

The impacts of technology-driven OHSM include reduced accident rates and enhanced sustainability. Haas and Cauda (2022) report a 12% reduction in fatigue-related incidents in US mining. Liu et al. (2024) note a 12% reduction in manufacturing downtime, and Rybak and Hassall (2025) show AI cut response times by 8%. However, interoperability challenges reduce efficiency by 10% in UK construction (Reveille et al., 2023). The digital divide persists, with developing regions constrained by systemic barriers (Kunodzia et al., 2024; Giri et al., 2025). The way forward involves interdisciplinary, context-specific frameworks. Practitioners should adopt modular technologies and ethical guidelines (Basiru et al., 2023; Tannous et al., 2025). Policymakers should harmonize regulations and offer SME incentives (Chaaya et al., 2025). Researchers must develop theoretical models and longitudinal studies (Saxena, 2024; Streit et al., 2024) and prioritize low-cost, context-specific solutions for developing nations (Fadhel & Alqurs, 2025). Investigating interoperability standards and sustainability metrics (Wang et al., 2024; Jain et al., 2024) will further align OHSM with global sustainability goals, as summarized in Table 7 and outlined in Figure 7. These strategies will institutionalize technology-driven OHSM, ensuring safer, more sustainable engineering workplaces globally.

Conclusion

This research has elucidated the pivotal role of emerging technologies—such as Artificial Intelligence, Internet of Things, Building Information Modeling, and wearable sensors—in reshaping Occupational Health and Safety Management (OHSM) to foster sustainable engineering practices in sectors like construction and manufacturing. The exploration reveals that these technologies drive significant advancements, enabling proactive hazard mitigation through real-time monitoring and predictive analytics, which substantially reduce workplace incidents. Moreover, integrating OHSM with sustainability principles enhances worker well-being and aligns with global sustainability objectives, creating a synergy between safety and environmental stewardship. However, the path to institutionalization is fraught with obstacles, including prohibitive costs, limited technical expertise, and disparities in adoption between developed and developing regions. The study also underscores gaps in theoretical models and long-term empirical data, which hinder the development of scalable frameworks.

These findings highlight the urgent need for innovative strategies to bridge inequities and standardize technology-driven OHSM.
Going forward, future research should focus on crafting interdisciplinary theoretical frameworks that integrate stakeholder perspectives to guide technology adoption. Empirical studies with extended timeframes are crucial to validate long-term safety and sustainability benefits. Additionally, research should prioritize inclusive frameworks tailored to resource-constrained settings, ensuring equitable access to technology. For practitioners, investing in workforce training and affordable technology solutions is essential to overcome barriers. Policymakers must advocate for global regulatory alignment and financial incentives to support small and medium enterprises. By addressing these priorities, stakeholders can transform OHSM into a cornerstone of sustainable engineering, ensuring safer and more resilient workplaces worldwide.

Declaration of Competing Interest
The authors declare that they have no conflicts of interest.

Funding
This research was conducted without any external funding.

Consent to publish declaration
Not applicable

Ethics and Consent to Participate declarations
Not applicable

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