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Analysis of the Implementation of a Digital Technology-Based Occupational Health and Safety Management System in the Manufacturing Industry in Indonesia

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ABSTRACT
This study examines the implementation of a digital-based Occupational Health and Safety Management System (OHSMS/SMK3) in the Indonesian manufacturing industry, focusing on effectiveness, challenges, and strategic implications. A qualitative case study approach was applied, involving purposively selected informants from managerial and operational levels. Data were collected through in-depth interviews, observations, and document analysis, and analyzed using thematic analysis. The findings indicate that the integration of digital technologies—such as e-SMK3 applications, web-based dashboards, and Internet of Things (IoT) sensors—enhances real-time incident reporting, risk monitoring, and safety performance evaluation. However, remains unevenly distributed across organizational levels, with higher adoption among managers and limited use among operational workers due to gaps in digital competence and system integration into daily workflows. The study further reveals that digitalization contributes not only to operational efficiency but also to improved data accuracy, transparency, and the development of a data-driven safety culture. Nevertheless, key barriers include infrastructural constraints, high investment costs, cybersecurity concerns, and socio-cultural resistance to technological change. From a practical perspective, these findings highlight the importance of workforce digital upskilling, user-centered system design, and robust data governance. From a policy perspective, regulatory support and incentives are essential to accelerate digital OHS adoption. This study contributes to the socio-technical systems perspective by emphasizing inclusive technology utilization across organizational levels. Future research should employ quantitative and longitudinal approaches to assess long-term impacts on safety performance and organizational resilience.

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INTRODUCTION

The Industrial Revolution 4.0 has brought about a major transformation in manufacturing processes through the integration of digital technologies such as the Internet of Things (IoT), cyber-physical systems, and artificial intelligence, which can improve operational effectiveness. However, this transformation also brings new challenges to occupational health and safety (OHS), particularly those related to human-machine interactions and the increasingly complex occupational risks in digital work environments (Nioata et al., 2025).

In the past, OHS management relied heavily on manual and administrative practices. As technology advances, the need to integrate OHS management systems with digital platforms that enable real-time monitoring, automated reporting, and risk data analysis (digital safety management systems) has emerged. Recent research shows that digital platforms can support efficiency of incident reporting, inspections, and factory safety audits with robust workflow automation (Koh & Tan, 2024).

International standards such as ISO 45001 are the primary framework for organizations to establish and maintain an effective occupational health and safety management system. ISO 45001 also supports a risk-based approach and continuous monitoring, which form the basis for the digitalization of OHSMS in many modern manufacturing industries. Implementation begins with a gap analysis to identify gaps, followed by awareness training, the development of procedural documents, internal audits, and external certification by institutions such as LRQA or BSJ. In Indonesia, this phase aligns with the OHSMS based on Ministerial Regulation No. 5/2018 and Presidential Regulation No. 74/2024 (YOHSana et al., 2022).

Implementing digital technology in OHS systems can improve an organization's ability to identify hazards, predict risks, and respond quickly to hazardous work conditions. For example, the use of wearable devices and IoT-based sensors supports in real-time monitoring of worker conditions and the work environment, thereby increasing the effectiveness of risk mitigation (Jiang et al., 2024).

Data-driven digital systems can improve the accuracy of incident reporting and provide historical data that can be analyzed for continuous improvement. This contributes to faster, evidence-based decision-making in accident prevention strategies and the development of a workplace safety culture (Abd et al., 2024).

While digitalization OHSMS offers significant benefits, research also identifies several implementation challenges, such as limited technological infrastructure, high initial investment costs, and the need for digital competency among OHS workers and managers. Furthermore, data privacy and cybersecurity concerns pose barriers to the adoption of digital systems in manufacturing environments (Jiang et al., 2024).

Several scientific studies in Indonesia have shown an accelerating trend toward digitalization in OHS document management and OHS monitoring systems based on digital technologies such as IoT. For example, research on the application of OHS document digitization to a construction project has improved document management efficiency and increased safety data transparency (Rizka, 2025).

The development of an IoT-based occupational health and safety monitoring system in an industrial area also demonstrates the technology's ability to provide early warnings of hazardous

conditions and increase worker safety awareness. This highlights the significant potential for adopting digital technology to strengthen risk management in the manufacturing sector (Mayori et al., 2025).

Although several studies have reviewed the digitalization of certain elements in OHS management, there is still a gap in comprehensive analysis of the implementation of digital-based OHS management systems in the context of the Indonesian manufacturing industry—including the evaluation of effectiveness, implementation barriers, and strategies for sustainable adoption.

Against the backdrop of rapid digital technology developments and demands for improved occupational safety performance in the national manufacturing industry, it is crucial to conduct research that analyzes how digital technology-based OHS management systems are implemented in practice and how these technologies contribute to achieving overall industrial safety goals. This research will provide theoretical insights and policy implications for standard setters, industry managers, and relevant stakeholders.

METHODS

This research uses a qualitative approach with a case study design, which aims to gain an in-depth understanding of the implementation of a digital technology-based occupational safety and health management system (SMK3) in the manufacturing industry in Indonesia. The qualitative approach was chosen because this research focuses on the process, experience, and dynamics of implementing a digital OHS system in an organizational context, which cannot be adequately captured through quantitative methods alone. The case study design is used to explore phenomena comprehensively and contextually in a real work environment, thus being able to describe the conditions of digital OHS management system implementation more fully.

This research was conducted at a manufacturing company in Indonesia that has implemented a digital technology-based OHS management system, either in the form of an integrated system or supporting digital applications such as e-SMK3, a digital incident reporting system, an OHS dashboard, or Internet of Things (IoT)-based monitoring technology. The research objects include OHS policies and procedures, the digital technology infrastructure used, and operational practices of OHS management in daily production activities.

The research subjects were determined using purposive sampling, which involves deliberately selecting informants based on their involvement in and knowledge of the implementation of a digital technology-based OHSMS. The informants included OHS managers, OHS staff, production managers, information technology personnel, and workers who directly use the digital OHS system in carrying out their duties. This selection is expected to provide diverse and comprehensive perspectives on the effectiveness and challenges of the system's implementation.

Data collection was conducted through several techniques, including in-depth interviews, direct observation, and document analysis. In-depth interviews were conducted to gather information related to perceptions, experiences, benefits, and obstacles in implementing a digital technology-based OHSMS. Observations were conducted to directly observe the use of the digital OHS system in operational activities, such as incident reporting, safety inspections, and monitoring of working conditions. In addition, document analysis were conducted on OHS policy documents,

standard operating procedures, work accident reports, digital system data, and the results of the company's OHS audits and evaluations.

The data obtained were analyzed using thematic analysis techniques, which were carried out through the stages of data reduction, data presentation, and conclusion drawing. At this stage, data from interviews, observations, and documentation were coded to identify key themes related to the implementation of the digital OHSMS, the level of technology utilization, the benefits perceived by companies and workers, implementation barriers, and efforts to improve system effectiveness. The analysis process was carried out iteratively until consistent patterns and meanings were obtained that were relevant to the research objectives.

To ensure validity and reliability, this study employed triangulation techniques, including both source and method triangulation. Information obtained from interviews was verified through observations and company documents. Furthermore, member checking was conducted with informants to ensure that the researcher's interpretations aligned with their experiences and perspectives. The entire research process was conducted in accordance with ethical research principles, including maintaining the confidentiality of informants' identities and company data and obtaining informed consent prior to data collection.

RESULTS

1. Overview of the Implementation of SMK3 Based on Digital Technology

The research findings indicate that the digitalization of SMK3 contributes significantly to improvements in efficiency, accuracy and safety culture. However, further analysis reveals that this contribution does not occur in a linear fashion, but rather through complex interactions between technology, people and the organization.

2. Forms of Implementation of the Digital K3 System

The results of the thematic analysis identified several main forms of implementation of digital technology-based OHS management systems, as presented in Table 1.

Table 1. Forms of SMK3 Implementation Based on Digital Technology

Implementation Aspects	Digital System Form	Main Function
Incident reporting	K3 mobile application	Real-time incident and near miss reporting
Safety inspection	Digital checklist	Recording of inspection results and K3 findings
Risk monitoring	IoT Sensors	Monitoring of temperature, gas, noise, and vibration
K3 Documentation	K3 e-Document	Storage of SOPs, work permits, and audit reports
Performance evaluation	K3 Dashboard	Visualization of KPIs and occupational accident trends

An analysis of the data in Table 1 shows that the digitalization of SMK3 is not merely a matter of replacing manual processes with technology, but represents a systemic transformation within the occupational health and safety (OHS) management cycle. The integration of mobile applications, web-based dashboards and IoT sensors indicates the formation of a closed-loop safety management

system that enables a continuous flow of data from the hazard identification stage through to performance evaluation.

The emergence of this integration pattern can be explained by organizations' need for rapid response times and accurate information in high-risk work environments. Digital systems enable reduced latency in incident reporting and strengthen predictive safety functions, particularly through IoT sensors capable of detecting workplace anomalies in real time.

Thus, these findings indicate that digitalization acts as an enabler for a paradigm shift from reactive safety towards proactive and predictive safety management, which was previously difficult to achieve in manual-based systems.

3. Level of Digital System Utilization by Workers and Management

The results of observations and interviews show that the level of utilization of the digital K3 system differs between user groups, as summarized in Table 2.

Table 2. Level of Utilization of Digital K3 Systems

User Groups	Utilization Rate	Usage Characteristics
K3 Manager	High	Data analysis, risk evaluation, management reporting
K3 Staff	High	Digital inspection and report verification
Production manager	Medium	Monitoring of K3 compliance
Operational workers	Medium–low	Incident reporting and digital PPE use

The data in Table 2 reveal significant disparities in the level of digital system utilization across user groups, reflecting structural gaps in the organization's digital capabilities.

The high level of utilization among managers and health and safety staff indicates that this group possesses:

- cognitive and technical access to the system as well as
- a strategic role in data-driven decision-making

Conversely, the low utilization among operational workers indicates the presence of barriers such as:

- limited digital literacy
- resistance to change
- a lack of system integration with daily work routines

This pattern suggests that technology implementation has not yet fully reached the operational level (shop-floor integration). In other words, digitalization remains at the stage of managerial-centric adoption, rather than an organization-wide embedded system.

This explains why the benefits of the system are not yet optimal, as the effectiveness of the digital SMK3 system is highly dependent on the collective participation of all levels of the organization.

4. Benefits of Implementing SMK3 Based on Digital Technology

This research identified several key benefits perceived by organizations and workers, as summarized in Table 3.

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Table 3. Benefits of Implementing Digital SMK3

Benefit Dimension	Key Findings
Operational efficiency	Reduction of reporting and inspection time
Data accuracy	More complete and documented incident data
Risk response	Early warning of dangerous conditions
Transparency	Open access to K3 data for management
Safety culture	Increasing worker awareness of K3

An interpretation of Table 3 shows that the benefits that emerge are multi-dimensional in nature and mutually reinforcing (interdependent effects).

- Operational efficiency arises from process automation
- Data accuracy improves due to digital traceability
- Risk response becomes faster through early warning systems
- Transparency strengthens organizational accountability
- Occupational health and safety (OHS) culture improves as a consequence of data visibility

Interestingly, this pattern shows that the benefits do not stand alone, but rather form a chain of causal mechanisms. For example:

increased transparency → increased awareness → strengthened OHS culture → reduced accident risk

Thus, digitalization acts as a catalyst in building a data-driven safety culture, rather than merely serving as a tool for technical efficiency.

5. Barriers to Implementing Digital K3 Systems

Despite providing significant benefits, this study also found several major barriers to implementing digital SMK3 (Table 4).

Table 4. Barriers to Implementing Digital OHSMS

Types of Barriers	Description
Infrastructure	Network and device limitations
Human Resources	Low digital competence of workers
Cost	Initial system investment and maintenance
Data security	Concerns about privacy and data breaches

Table 4 reveals that implementation barriers are socio-technical in nature and interrelated, rather than standing as isolated factors.

- Infrastructure limitations → hinder system access
- Low staff competence → reduces utilization
- Investment costs → limit scalability
- Data security concerns → reduce user trust

This pattern indicates the presence of systemic constraints, where a failure in one element impacts the entire system.

These findings illustrate that the digitalization of SMK3 cannot be viewed merely as a technological project, but as an organizational transformation requiring simultaneous readiness across technological, human, and governance aspects.

6. Summary of Key Results

Overall, the research results show that the implementation of a digital technology-based OHS management system in the Indonesian manufacturing industry has been functioning effectively and has had a positive impact on occupational safety performance, although it still faces challenges in the aspects of human resources, infrastructure, and data security.

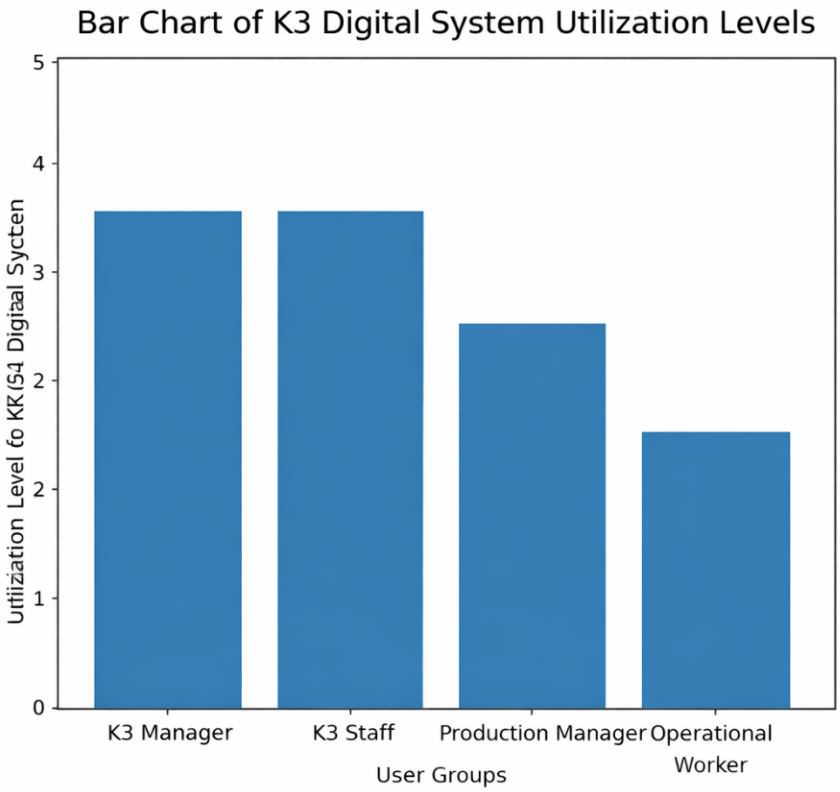

Figure 1. Bar Chart of Digital K3 System Utilization Level

The interpretation of Figure 1 reinforces the findings in Table 2 by demonstrating a utilization gradient based on organizational hierarchy.

The emerging pattern reflects a top-down utilization bias, wherein:

- managerial level → intensive use of the system for analysis and reporting
- operational level → limited to basic functions

This phenomenon indicates that digital systems have not yet been fully internalized as primary operational tools at the operational level, but are still perceived as administrative or reporting tools.

Analytically, this situation can be explained by:

- a lack of user-centered system design
- insufficient practical training
- poor integration of the system with operational workflows

Consequently, the system's effectiveness is suboptimal, as the data generated does not fully represent real-time conditions on the ground.

DISCUSSION

Research shows that the implementation of a digital occupational safety and health management system (SMK3) in the manufacturing industry in Indonesia has positively contributed to increased operational efficiency, reporting accuracy, and a culture of safety. The use of Internet of Things (IoT) devices, a web-based OHS dashboard, and an e-SMK3 system facilitates real-time incident reporting, data-driven risk monitoring, and integrated electronic document storage. These findings confirm that the implementation of digital systems can accelerate evidence-based decision-making and strengthen organizational transparency in safety management.

However, the main obstacles faced include limited technological infrastructure, initial investment costs, and low digital literacy among operational workers. This suggests that successful implementation is determined not only by technological sophistication but also by human resource readiness and company policy support.

Theoretically, the results of this study support the socio-technical systems approach, where the success of technological innovation in the context of work organizations is highly dependent on the balance between technical factors (digital systems, infrastructure) and social factors (competence, safety culture). The integration of digitalization into OHS is also in line with the principle of continuous improvement in ISO 45001:2018, which emphasizes the importance of ongoing risk monitoring and data-driven decision-making (evidence-based OHS management).

The implementation of OHS digitalization effectively supports increasing the maturity level of safety culture by enabling real-time monitoring, rapid reporting, and predictive data analysis. Technologies such as mobile applications, IoT, and AI facilitate the transition from compliant to proactive or generative levels in maturity models such as the Hudson model or the UK Coal Journey model (Khatami et al., 2024; Sukoco & Puariesthaufani N, 2023).

Safety Culture Maturity Models such as Hudson (pathological, reactive, calculative, proactive, generative) or the UK Coal Journey assess progress from basic compliance to a proactive culture. Digitalization drives this shift through data-driven decision-making and employee engagement. The generative level is achieved when organizational commitment, communication, and learning are integrated with technology (Machfudiyanto et al., 2025).

The results of this study reinforce previous findings highlighting the importance of implementing digital-based occupational safety and health (OHS) management systems across various industrial sectors. Globally and nationally, OHS digitalization has proven effective in improving operational efficiency, incident reporting accuracy, and safety culture maturity.

Research by Ramadhan et al. (2025) shows that the implementation of the ISO 45001 standard in the Indonesian chemical industry significantly improves organizational performance through operational process efficiency and simplification of digital data-driven decision-making systems. This finding is consistent with research by (Sari et al., 2025), which identified that an ISO 45001-based OHS system supported by a digital platform can accelerate risk identification and improve incident response capacity in the healthcare sector.

Furthermore Fakhri et al. (2026) found that the adoption of digital systems in OHS management promotes safety culture maturity through increased worker engagement and reporting transparency. Furthermore, (Nugraha et al., 2024) introduced a new paradigm for safety management in the digital era, where the synergy between safety management, information

technology, and data analytics forms the foundation for creating organizations that are resilient to occupational risks.

Historically, efforts to digitize the OHS system in Indonesia have been based on research (Asih & Latief, 2021), which confirms that the successful implementation of ISO 45001 is highly dependent on the integration of government policies with technological readiness at the organizational level. Thus, all previous research demonstrates that digital transformation in the OHS system is not merely a technical issue but also part of a national strategy to increase industrial productivity and competitiveness.

The findings of this study indicate that the implementation of a digital technology-based occupational safety and health management system (digital OHSMS) in Indonesia's manufacturing sector makes a significant contribution to improving operational efficiency, reporting accuracy, and strengthening the safety culture. However, a more in-depth analysis reveals that this contribution does not occur in a linear fashion, but rather through complex interactions between technological, human, and organizational dimensions. The integration of digital technologies, such as e-SMK3, web-based dashboards, and Internet of Things (IoT) sensors, has been shown to improve the visibility of safety data and support evidence-based decision-making. On the other hand, digital competence gaps among users create disparities in the utilization of the system, which ultimately affects the overall effectiveness of implementation.

These findings suggest that the success of SMK3 digitalization is largely determined by the degree of alignment between the technological capabilities adopted and the readiness of the human resources operating them. The higher level of utilization at the managerial level compared to the operational level indicates that digital systems still tend to be manager-centered, not yet fully integrated into day-to-day work activities on the production line. This situation reinforces the argument that digital transformation in the context of occupational health and safety (K3) requires not only technological innovation but also implementation strategies capable of driving inclusive and equitable adoption across all levels of the organization.

When compared with previous research, these findings are consistent with the studies by Ramadhan et al. (2025) and Sari et al. (2025), which demonstrate that the digitalization of OHS systems can improve operational efficiency and accelerate risk identification. Furthermore, the research by Fakhri et al. (2026) also confirms that the use of digital technology contributes to the enhancement of safety culture through increased transparency and worker engagement. However, this study makes an additional contribution by highlighting the disparity in technology utilization across organizational levels as a crucial factor that has not been extensively explored in previous studies. Thus, this study expands the understanding that the effectiveness of digitalization is determined not only by the existence of the system, but also by the distribution of its use within the organizational structure.

Theoretically, the findings of this study reinforce the relevance of the socio-technical systems approach, which emphasizes that the successful implementation of technology within an organization depends heavily on a balance between technical and social factors. Furthermore, the results of this study also support the safety culture maturity framework, in which digitalization acts as a catalyst for the transition from a reactive safety culture towards a proactive and generative one. Moreover, this study adds a new perspective that achieving a higher level of safety culture maturity

requires the democratisation of access to and the comprehensive utilization of technology across all levels of the organization, not merely at the managerial level.

From a practical perspective, the findings of this study underscore the importance of human resource capacity building through ongoing digital literacy training, as well as the need for user-centred design to ensure easier adoption by operational staff. Furthermore, the integration of digital systems with operational workflows is a key factor in ensuring that technology functions not merely as a reporting tool, but as an integral part of day-to-day work processes. Strengthening policies related to data security and governance is also crucial for enhancing user trust in the implemented digital systems.

Overall, this discussion underscores that the digitalization of SMK3 is a multidimensional organizational transformation process requiring a holistic approach. Successful implementation cannot be achieved through the adoption of technology alone, but must be supported by comprehensive organizational readiness, including aspects of competence, culture, and governance. Consequently, the digitalization of OHS must be positioned as a long-term strategy integrated into efforts to improve safety performance and industrial sustainability in the era of digital transformation.

CONCLUSIONS

This study concludes that the implementation of a digital technology-based occupational safety and health management system (digital OHSMS) in Indonesia's manufacturing industry is capable of improving operational efficiency, data accuracy, and transparency, as well as strengthening a data-driven safety culture. The integration of technologies such as e-OHSMS, web-based dashboards and Internet of Things (IoT) sensors enables more responsive, real-time and integrated risk management.

However, the effectiveness of implementation is not yet optimal due to a disparity in utilization across organizational levels, where system usage remains dominated by managerial levels, while operational workers demonstrate a lower adoption rate. This indicates that digitalization has not yet been fully internalized as a comprehensive working system.

Furthermore, the benefits of digitalization are multidimensional and interrelated, but their sustainability is heavily influenced by socio-technical factors, such as infrastructure readiness, the digital competence of the workforce, and policy support and data governance. Consequently, the digitalization of SMK3 must be understood as an organizational transformation process that demands alignment between technology, people, and institutional systems.

This study underscores the importance of inclusive implementation strategies through the enhancement of digital literacy, the integration of systems into operational processes, and the strengthening of data security policies. Moving forward, further research is needed to examine the long-term impact of SMK3 digitalization on safety performance and organizational resilience more broadly.

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