Digital Occupational Safety and Health to Enhance Worker Performance: Challenge From Industry 4.0 to Industry 5.0

Muliati Usman[1*], Nashrillah[2], Syarifah Evi Zuhra[3]
[1,2,3]Management Department, Faculty of Economics and Business,
Universitas Syiah Kuala, Darussalam, Banda Aceh, Indonesia
*Corresponding author : muliatiusman@usk.ac.id

ABSTRACT

This study aims to explore the impact of digital occupational safety and health (OSH) on worker performance in addressing the challenge of the transition from Industry 4.0 (I4.0) to Industry 5.0 (I5.0) through a human-centered approach. The systematic literature review (SLR) method is adopted by carrying out the procedure of Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). The findings indicate that digital OSH is a critical aspect for boosting worker performance. Meanwhile, building synergy between human and technology is crucial to boost worker performance in industrial evolution. Therefore, this study also identified that a human-centered approach emerges as a mediator in the link between digital OSH and worker performance. Specifically, this study showed several digital OSH practices i.e. mental and physical health, technological stress, technological costs, social support, and systems and processes. Consequently, there are some key drivers of digital OSH i.e., empowerment, working conditions and work environment, safety culture, and policy and procedure. Furthermore, the impact of digital OSH on worker performance can be found in three dimensions; productivity, attitude and behavior, and work quality. The current study contributes to presenting new insights by highlighting challenges and key drivers on the link between digital OSH and worker performance using a human-centered approach as the critical strategy in the transition of I4.0 to I5.0.

Keywords:
Digital occupational safety and health; Worker performance; Industry 4.0; Industry 5.0; Human-centered approach.

Introduction

The Fourth Industrial Revolution, commencing in the 1980s represents a period of profound intensification in digital integration. Core technologies, including artificial intelligence (AI), the Internet of Things (IoT), automation, and cyber-physical systems have become increasingly embedded in the daily life of humans. This revolution facilitated the development of smarter, more efficient, and highly interconnected production processes change (Aksoy et al., 2023). Technological advances cause significant changes in industrial evolution. It is also crucial to ensure that the evolution of OSH always follows revolutionary developments in industry (Milea & Cioca, 2024). Indeed, adoption of I4.0 technologies is urgent to promote a safe working environment that is important to maintain OSH (González-Cañizalez et al., 2024; Kabiesz et al., 2025). It reduces human exposure to hazardous conditions due to the risk of occupational accidents (Min et al., 2019; Dos Santos et al., 2025; Emery et al., 2023) that can have a significant impact on workers' health and safety (Polak-Sopinska et al., 2019).

Indeed, OSH in the I4.0 is closely linked to improved worker performance. It develops digital technology as a means to protect and improve workers' welfare. Digital OSH functions as a mechanism to ensure that digital transformation improves productivity, but also workers' safety and health with the main objective to improve worker performance in a sustainable manner. Many researchers found the influence of digitalization of I4.0 in the area of OSH in increasing worker performance (e.g., Vuori et al., 2019; Demikhov et al., 2023; Zorzenon et al., 2025; Brocal et al., 2019). Furthermore, there is growing and convincing evidence that ensuring a healthy and safe work environment positively influences worker performance (Karakhan et al., 2021). This impact is evident in terms of productivity (Lamm et al., 2007; Moraru, 2024), individual behavior and attitudes (Beno, 2021), as well as the overall quality of work (Moraru, 2024). In this context, I5.0, which places humans at the forefront, fosters the development of sustainable, safe, and responsible technologies for occupational safety and health (OSH). Such advancements ultimately enhance worker performance (Nguyen et al., 2024). By adopting a human-centered approach, organizations can strengthen collaboration between technological innovation and human capabilities, leading to greater improvements in worker performance.

However, the concept of Industry 4.0 in today's dynamic era is gradually evolving toward I5.0. This transition demands careful consideration of several issues, particularly the urgency of adopting a human-centered approach (Saniuk et al., 2024). The move into the digital era and the integration of advanced technologies within organizations and businesses present not only opportunities but also significant challenges (Moraru, 2024). Technologies associated with Industry 4.0 introduce various risks, especially in the management of occupational safety and health (Min et al., 2019). Organizations must prepare not only for the promising future offered by digital innovation but also for the potential drawbacks it may bring (Darabont & Bejinariu, 2024). In the context of I4.0, adoption of these technologies can pose both physical and psychological risks such as contributing to certain types of cancer, increasing workloads, creating job complexity (Min et al., 2019), generating technostress, and exposing organizations to cybersecurity threats (Koh & Tan, 2024).

By contrast, I5.0 highlights challenges related to organizational and human factors, arising from the complexity of human-technology interaction (Brocal et al., 2019; Ozmen Garibay et al., 2023). A central concern is how to improve organizational outcomes without displacing human workers (Nahavandi, 2019). The most pressing challenge is the fear of machine domination, which could fundamentally reshape the job market and lead to widespread job losses due to automation. Many occupations are at high risk of being automated as digital technologies advance (Müller et al., 2019; Frey & Osborne, 2017; Schwab, 2016). Ultimately, the critical issue lies in whether technology will replace human labor in an increasingly competitive work environment. This raises the fundamental question: will technological advancement eliminate the role of human workers?

The I5.0 emerges to offer significant potential across multiple domains that guarantee human value (Aksoy et al., 2023). The human factor becomes central in developing intelligent cyber-physical-socio-technical systems that create a new work ecosystem characterized by radical changes in methods, processes, and development. It gives rise to emerging occupational risks that must be addressed by the field of safety science (Ávila-Gutiérrez et al., 2022). Several studies identified the important role of the human-centered approach on worker outcomes in the transition from I4.0 to I5.0 (e.g. Baseman et al., 2026; Korte et al., 2024; Mullaney, et al., 2011; Arana-Landín et al., 2023; Carayon et al., 2015; Saniuk et al., 2024; Dodoo et al., 2024). At the same time, a previous study by León et al. (2024) confirmed that I5.0 positively enhances organizational sustainability. The study highlights the need for effective implementation strategies of a human-centered approach. The digital technologies of I4.0 will be employed and implemented as technologies of I5.0 with a renewed focus on enhancing and leveraging them to create value for the human element. Thus, the functions of technology do not only to increase the performance of workers such as productivity. It also supports the physical, mental, and sustainable well-being of workers (European Agency for Safety and Health at Work, 2022). With the advent of I5.0 in smart manufacturing systems, workers will need to evolve into resilient, digitally skilled professionals. While the I4.0 era focused primarily on integrating technologies, I5.0 places humans at the center (human-centered society) in utilizing these technologies. To this end, the concept of safety 5.0 has emerged as a critical framework for addressing advanced safety in the upcoming advanced industrial era (Alzaabi, 2024; Papacharalampopoulos et al., 2026) that can act as a strong mediation on worker performance in the transition from I4.0 to I5.0.

A well-formulated approach is essential to address the challenges associated with OSH digitalization in order to foster worker performance driven by I4.0 to I5.0. Navahandi (2019) asserted that an approach to address this challenge is to introduce the concept of I5.0 in responding the technology advancement. While, Moraru (2024) claimed that it is important to detect and systematize the current challenges of the world of work from a safety perspective. Consequently, there is a need to identify emerging technologies used in OSH management practices and to summarize their potential benefits in mitigating workplace safety hazards and their impact on key performance indicators (Karakhan et al., 2021). Therefore, the human-centered approach was essentially developed to address the various challenges arising from massive digitalization. However, lack of studies focused on the impact of drivers of digital OSH on worker performance in dealing with the current challenge in the context of industrial evolution. In this context, this study aims to review the impact of digital OSH on increasing worker performance in the movement of I4.0 to I5.0 through the role of a human-centered approach as a mediator. An integrated review is needed for the development of research through a specific framework of this relationship. For this reason, the research question of the study is as follows:

1. What are the potential challenges of digital OSH in the I4.0 to enhance worker performance toward I5.0?
2. What are the key drivers of digital OSH to enhance worker performance for further application toward I5.0?
3. How does digital OSH enhance worker performance when dealing with challenges from I4.0 to I5.0 through the mediating role of a human-centered approach?

Literature Review

Worker Performance in the Transition I.4 0 to I.5 0

Performance refers to the results or achievements accomplished by the worker within a certain period, measured using specific indicators or criteria set by the organization to assess the worker's level of capability. As stated by Abdullahi et al. (2025), worker performance is considered an indicator of effectiveness and efficiency in carrying out tasks related to business or organizational goals. Thereby, worker performance refers to the level of effectiveness, productivity, and contribution with which an individual worker carries out their job duties and responsibilities. It often involves meeting job expectations, contributing to team goals, and achieving positive outcomes for the organization (Mohammad et al., 2025). While worker performance in the current era has moved to the issue of the digitalization of technologies in the I4.0 era. Technology has fundamentally altered the nature, timing, and location of work, affecting employers, workers, and work processes (Beno, 2021). It indicated that technology is a strategic means to enhance the effectiveness, productivity, and quality of worker performance in the digital era.

Several researchers revealed that digitalization has brought about significant changes in the workplace. These findings revealed a strong relationship between digital literacy and worker performance (e.g. Ibrahim et al., 2022; Abas et al., 2019; Karakhan et al., 2021; Arana-Landín et al., 2023). Digital literacy fundamentally improves worker performance by making work faster, more efficient, more accurate, and more flexible. At the same time, digital transformation in the era of I4.0 to 5.0 has redefined workplace dynamics, shaping how workers interact, cooperate, and adapt to technological advancement by synergizing human and digitalization. I5.0 brings increased sustainability and worker performance through human-machine collaboration (Mourtzis, et al., 2024). There is an urgent need to boost performance while retaining human workers (Navahandi, 2019). However, it is a fact that I5.0 is relatively new and the importance of this issue is not yet well-defined (Oeij et al., 2024). There is a very limited body of research that extensively reviews worker performance in relation to the transition from Industry 4.0 to Industry 5.0.

The Role of Digital OSH on Worker Performance in the Transition I.4 0 to I.5 0

The concept of OSH in the digital era is closely related to how technology and digitalization affect workplace safety and health. The use of automated systems, sensors, robots, and digital data offers many benefits. In this term, the current trend of OHS relates to the ability of firms to adopt and leverage digital technologies, digitalize their products or services, and create new value through a digitally-driven business model (Queirós et al., 2025; Kastelli et al., 2024). Recent studies have revealed the advantage of digital OSH to promote various individual outcomes in terms of I4.0. Specifically, previous studies found that digitalization of OSH in I4.0 influenced performance overall in terms of worker well-being. It provided better working conditions and work environment in helping to reduce the risk of occupational health and safety, both physical and psychological (e.g. Zorzenon et al., 2025**;** Bulboacă et al., 2024; da Silva & Amaral, 2019; Arana-Landín et al., 2023; Liu et al., 2025; Borges et al., 2021; Yassaee & Mettler, 2019; Muresan et al., 2024; Aljelaifi et al., 2025).

Digital OSH is an important aspect of worker performance in responding to the constraints of industrial evolution. However, in the context of I5.0, building synergy between humans and technology is crucial in implementing digital OSH in today's industrial evolution (Villani et al., 2018). I5.0 emerges as a complementary and transitional concept from the technology-driven I4.0 toward a human-centered industry, where worker well-being is prioritized while maintaining performance. Future perspectives on human-centricity aim to empower individuals in order to improve human-robot interaction within dynamic and complex industrial systems (Alves et al., 2023). This has led to the identification and implementation of reliable and sustainable solutions to ensure worker safety and health (Milea & Cioca, 2024) in response to technological advancement in the I4.0. Technological advancements have brought about a number of consequences (positive and negative) for the safety and health of workers. Consequently, researchers have highlighted the challenge and opportunity of I4.0 to I5.0 (e.g. Longo et al., 2020; Mourtzis et al., 2023; Nahavandi, 2019). Considering the rapid transformation of organization or business processes, this study considers that it is

necessary to highlight the challenges and drivers for the future direction of digital OSH on worker performance extensively in the context of I4.0.to 5.0 mediated by the role of the human-centered approach.

Methods

This study adopts the systematic literature review (SLR) method by referring to the procedure of PRISMA. It was developed to improve the transparency and quality of reporting of systematic reviews and meta-analyses, thus ensuring a clear and unbiased literature selection process. The procedure generally conducted is by performing selection of articles, search strategy, data extraction, and data analysis (Page et al., 2021). Furthermore, this study provided documentation to enable readers to evaluate the completeness and potential bias in literature selection by referring to 3 (three) phases, i.e., identification, screening, and eligibility. The steps of a systematic literature review are illustrated in Figure 1.

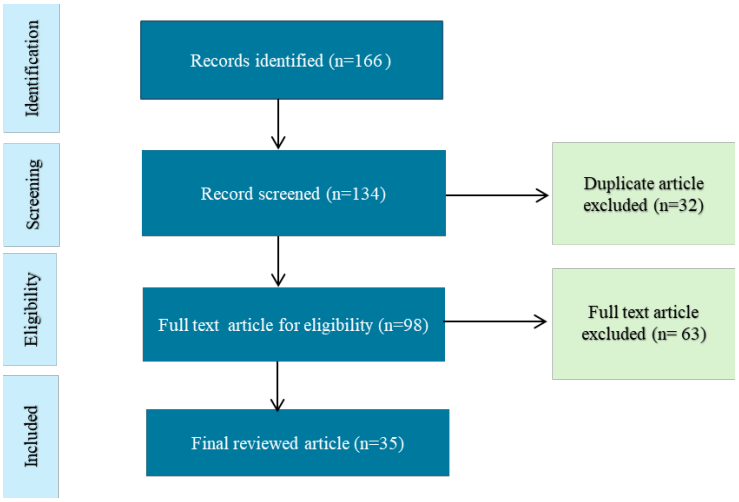

Figure 1. Reporting Items for Systematic Literature Reviews (Adoption of PRISMA)

Identification

In a systematic literature review (SLR), the process of identifying and combining keywords with Boolean operators is a crucial step in building a search strategy. The OR statement is used to add more variations or synonyms to ensure the search covers a wide range of related terms. Meanwhile, the AND statement is used to combine several important concepts to filter literature that is more relevant to the main topic (safety, worker performance, and I4.0 to 5.0). The use of quotation marks ("") to combine terms consisting of two or more words so that the search refers to the term as a single unit, namely by entering the keyword ("digital workplace safety" OR "digital occupational health" OR "digital safety management" OR "digital health and safety" OR "e-safety" OR "smart safety") AND ("worker performance" OR "worker performance" OR "worker productivity" OR "performance management" AND ("I4.0" OR "Fourth Industrial Revolution" OR "I5.0" OR "Fifth Industrial Revolution" OR "advanced manufacturing technologies" OR "digital transformation") AND ("challenges" OR "issues" OR "barriers" OR "opportunities" OR "impacts"). To obtain as much relevant literature as possible, the search uses databases from Scopus, Web of Science, ScienceDirect, Emerald, Taylor Francis, SpringerLink, Sage Journals and Google Scholar. The search results through identification produce the most relevant articles on Digital OSH, worker performance, and the challenges of I4.0 and I5.0.

Screening

Screening is part of the process of screening studies before in-depth evaluation. The goal is not to directly determine final eligibility but to filter out studies that are clearly irrelevant (Page et al., 2021). At this stage, as many as 166 articles were reviewed. Furthermore, the 32 duplicate articles were removed. These articles were indexed in multiple databases, so they had to be eliminated. Finally, the remaining articles were 134 for further analysis. In the screening stage, inclusion is the process of selecting articles that pass the SLR selection process. Therefore, this study applied inclusion and exclusion criteria based on the year of publication between 2015 and 2026, the use of the

English language, and topic relevance to ensure only high-quality and relevant articles were used. High-quality articles are those published in non-indexed journals without peer review. The screening results eliminated 36 articles, leaving 98 articles for further assessment.

Eligibility

The eligibility stage is a further evaluation of studies that pass screening. This is an in-depth assessment to determine whether the study is truly eligible for inclusion. For all papers not eliminated in the previous selection, articles will be thoroughly reviewed and selected based on the eligibility criteria. This study read as many as 98 articles in full-text (full-text), including the title, abstract and the entire article. Strict testing was carried out to identify eligible articles. A total of 45 articles were eliminated because they did not fully focus on the requirements of this study. Thus, the samples were reduced to 53 articles.

Quality Assessment

A total of 53 articles were assessed for quality following the guidelines suggested by Mohammed Shaffril et al. (2020). The articles were classified into three categories: low quality, moderate quality, and high quality. Of these, 18 articles were assessed as low quality, leaving 35 articles that met the required standards for inclusion in the review. Figure 1 represents the steps for the systematic literature review process of the study using the PRISMA flow.

Results

Descriptive Analysis

The results of this study are presented using descriptive analysis to improve comprehension, which involves background information from the reviewed articles, including the distribution of articles based on the number of studies, year of publication, country of origin, industry, and methods used by the reviewed studies (Synder, 2019). The annual publication of the reviewed articles is depicted in Figure 2. The graph shows that the highest number of articles overall can be found in 2024 (10 articles), 2025 (8 articles), and 2021 (6 articles). In 2019 and 2022, each had three articles. While, in 2023 and 2026, each had two articles and the remaining year, namely in 2015, only one article. To understand the differences in reviewed articles across countries, this study collected data from 22 countries (see Figure 3). The highest number of articles was conducted by Poland, Portugal, Sweden, and Spain, with three articles each. The following countries, the USA, Saudi Arabia, Italy, Romania, and Taiwan, each contributed two articles. Meanwhile, several countries contributed only one article: Ecuador, Germany, Brazil, the United Arab Emirates, Canada, Switzerland, the United Kingdom, Korea, Malaysia, Romania, Mexico, Egypt, Japan, and Switzerland.

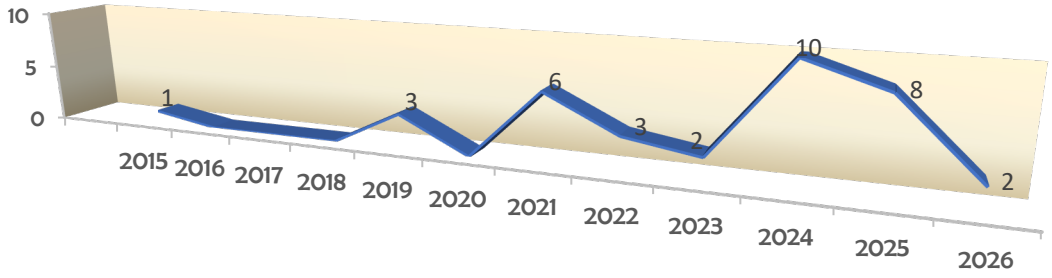

Figure 2. Historical Publication Trend by the Year

Furthermore, Figure 4 shows the distribution of articles by the type of industry. The organizations or companies involved in this review were primarily from studies conducted in the general sector (13 articles), followed by manufacturing (7 articles), and construction (6 articles). Companies in the logging, oil, gas, mining, and transportation sectors contributed three articles, while the healthcare sector contributed two. The sectors with the lowest contributions to this study were the logistics, ride-hailing, delivery, and house chore services sectors, the education sector, and the public sector, each with one article. Figure 5 illustrates the history of the articles based on the methodology. This study employed several methods, i.e. quantitative, qualitative, review, and mixed. Quantitative methodology was used in the majority of publications, with 12 articles. Review methods involved nine publications, qualitative methods involved eight publications, and mixed methods involved 4 articles.

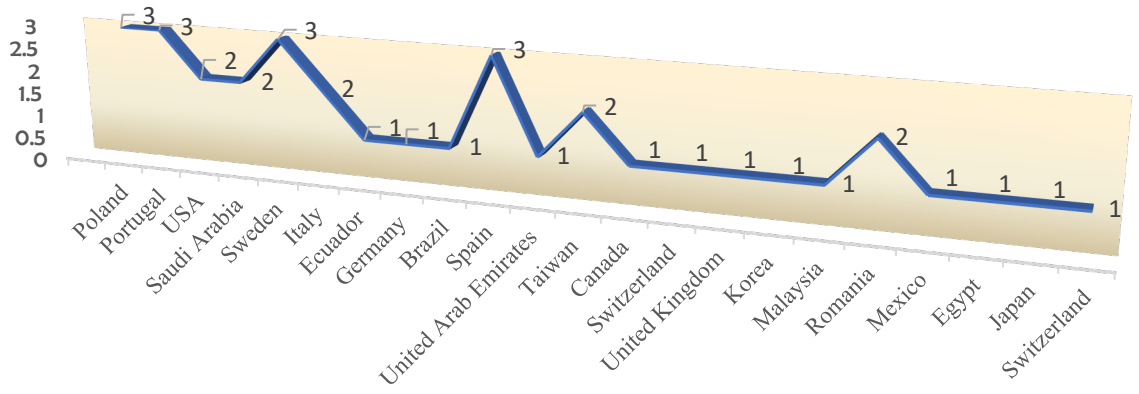

Figure 3. Historical Publication by the Country

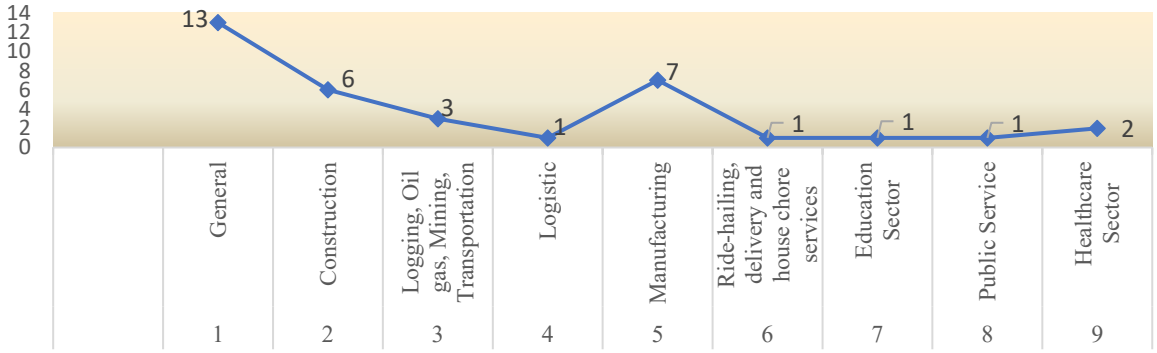

Figure 4. Historical Publication by the Type of Industry

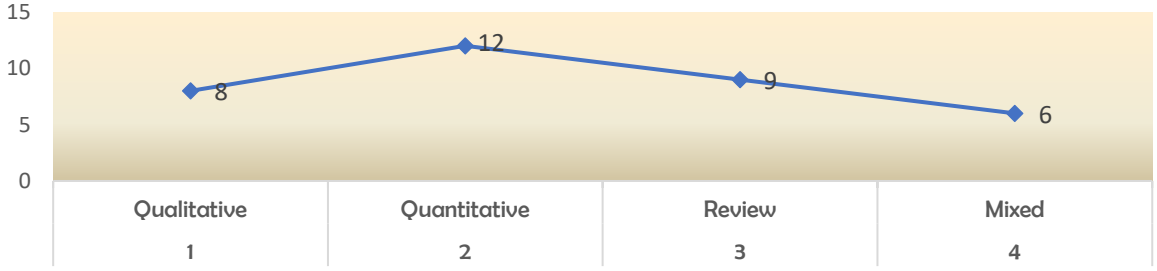

Figure 5. Historical Publication by the Methodology

Thematic Analysis

Thematic analysis is a method used to systematically identify patterns and themes and relate them to research questions. Good thematic analysis demonstrates a clear link between data, themes, and the research question (Braun & Clarke, 2023). The results of this study were synthesized using thematic analysis that was conducted on 35 articles. The themes are divided into three categories, namely drivers of digital OSH, challenges of digital OSH and worker performance in I4.0 to 5.0 (see Table 1). The first theme is the challenge of digital OSH that involves five sub-themes, i.e. mental and physical health, technostress, technology cost, social support and system & process. The second theme, namely drivers of digital OSH, consists of five sub-themes; namely empowerment, working conditions and work environment, safety culture, policy and regulation, and human-centric approach. Lastly, the third theme is worker performance, which is divided into three sub-themes i.e. productivity, work behavior and work quality.

Challenge of Digital OSH in the I4.0 to I5.0

This section presents detailed results regarding the analysis of the identification of digital adoption challenges in the transition era from the Fourth Industrial Revolution (I4.0) to the Fifth Industrial Revolution (I5.0). This study has conducted an analysis and found that there are several digital OHS challenges faced due to the Fourth Industrial Revolution technology, namely mental and physical health, technological stress, technological costs, social support, and systems & processes. The first challenge of digital OHS in the transition from I4.0 to I5.0 is mental & physical health. While Koh and Tan (2024) revealed that mental and physical health is a catalyst for digital OHS adoption challenges. Palumbo and Cavallone (2024) emphasized that increasing individual and collective understanding of stressors associated with digital transformation can encourage greater recognition of psychosocial risk factors in the workplace and encourage the adoption of formal and informal strategies to improve worker well-being. Indeed, this challenge is clearly contrary to the concept in the Fifth Industrial Revolution that workers should be treated with human values, especially regarding their roles with the aim of promoting worker well-being, both psychologically and physically. The second challenge of digital OSH in the workplace is technostress. A previous study by MacEachen et al. (2025) found that the adoption of digitalization in the workplace through online classroom teaching has caused technostress in Canadian teachers and tutors due to unequal occupational conditions. Similarly, a study by Cheng et al. (2024) found evidence that numerous work hazards include technostress accommodated by heavy reliance on ICT at the workplace. While, a study by Koh and Tan (2024) identified that improper use of technology can lead to stress and cognitive overload. Workers with lower digital skills may struggle to keep up with rapidly changing technologies, especially if adequate training is lacking. Thus, technostress hinders the implementation of digital OHS because workers lack the readiness to master digital skills. Ultimately, the I5.0 approach to synergizing the roles of humans and technology cannot be realized as intended. In the transition era from I4.0 to I5.0, building synergy between humans and machines will certainly be problematic due to the issue of technostress.

Technology cost was also considered as one of the challenges of digital OSH implementation. A study by Cagno et al. (2024) has found that cost is a key barrier in adopting digital occupational safety in metalworking Small and Medium-Sized Enterprises (SMEs) due to the investment and operational cost. Similarly, a study by Dodoo et al. (2024) found that high-cost implementation is the organizational challenge of utilizing digital technologies in managing OSH in high-risk occupations. Therefore, technology adoption in the era of the IR 5.0 has dominated OSH activities. In this term, cost will become an important issue when the organization is required to support the finance for digitalization in implementing OSH practices. Social support is a challenge for digital OSH practices when organizational members do not have awareness of the importance of providing support for the successful implementation of digital OSH in the workplace. Several studies emphasized the importance of a human-centered approach to address the challenge of social support in the context of I4.0 to I5.0. For instance, a study by Müller, et al. (2019) found that worker acceptance is an important factor for the success of I4.0 when dealing with OSH technology. It is mostly related to the fears of being replaced, lack of support, and lack of competencies. Developing commitment among organization members is a clear strategy for the introduction of I4.0 to be a success. Indeed, the organization will encounter problems when the organization's members are unable to provide support for the implementation of OSH digitalization in the workplace.

System and process is the last challenge in applying digital OSH. Several researchers found that systems and processes determine the failure of workers to adopt digital OSH in the modern work environment. A study by Navarro Claro et al. (2025) found that aligning safety systems through key people management practices such as planning, participation and continuous evaluation positively influences organizational performance. While, Yassaee and Mettler (2019) found the mental pressure caused by such an ineffective system significantly reduces worker willingness to adopt digital OSH. Milea and Cioca (2024) emphasized that it is crucial for the digital OSH practice to consider the complexity of work activities through an analysis of all elements of the work system components (personnel, workload, work tools/equipment, and work environment. Thus, systems and procedures that do not support the implementation of digitalization aligned with the I5.0 concept will create a problem for all parties involved. System and process is particularly closely related to a series of processes implemented in the form of an I5.0 approach through the human-centered approach concept. Therefore, it is important for organizations to enhance the effectiveness of occupational health services, establish adequate support systems for the implementation of occupational health programs, develop occupational health standards based on scientific risk assessment, improve the capacity and quality of human resources in occupational health, create well-organized registration and data systems, reinforcing research activities in the field of occupational health (Goldstein et al., 2001).

Drivers of Digital OSH in the I4.0 to I5.0

This study conducted a review on the challenges of digital OSH that result in several key drivers such as empowerment, working conditions and work environment, safety culture, policy and procedure, and human-centric approach. Firstly, empowerment is the most important driver of digital OSH. A study by Milea and Cioca (2024) found that worker empowerment is to ensure the continuous personal and professional development of workers in the context of occupational safety in the transition from I4.0 to I5.0. Thus, to overcome challenges associated with limited digital competencies, organizations should implement strategic initiatives aimed at increasing workers' familiarity and proficiency in the use of digital OSH systems. Similarly, a study by Papacharalampopoulos et al. (2026) found that integrating human insights with cyber systems in training enhances knowledge transfer, supports effective collaboration between workers and intelligent technologies, and encourages a human-centered approach in production processes. In this context, Aksoy et al. (2023) stated that skills development to promote essential I5.0 competencies can be achieved through continuous education and training to help workers improve their technological adaptability. The second aspect is working conditions and work environment. This study indicated that a positive and collaborative work environment significantly influences the performance of OSH. For instance, a study by MacEachen et al. (2025) found that the work environment influences the teaching work and health of the teacher. The adoption of digitalization in the work environments during COVID-19 poses occupational health risks for teachers when conducting online learning that causes difficult student engagement and moral discomfort. As stated by Hiba (2002), the Global Strategy of OSH by World Health Organization (WHO) identifies eight key priority areas; and they are strengthening national and international policies related to occupational health and promoting the creation of healthy work environments and practices.

The third driver is safety culture, which refers to the shared values, attitudes, and practices related to safety within an organization. Some researchers indicated that promoting a safety culture in the workplace acts as a driver of worker safety in the context of the transition from I4.0 to I5.0 (e.g. Milea & Cioca, 2024; Pasman & Behje, 2024; Aksoy et al., 2023). These findings indicated that the cultural shift to digitalization and automation known as I4.0 has led to changes in OSH practices that encourage sustainable processes in the era of I5.0. Thereby, a strong awareness of the safety culture enhances workers' sense of security and reduces workplace accidents. Indeed, I5.0 digital asserts technology as a catalyst for innovation and enhanced performance. It serves as both an enabler and a driver of digital transformation (Kastelli et al., 2024) to support OSH running successfully in the management process from the point of view of the employer and worker (Darabont & Bejinariu, 2024).

The fourth driver is policy and procedure. It indicated that clear and well-implemented policies provide guidance, structure, and consistency in organizational operations, ultimately supporting improved worker performance. Policy and procedure have been claimed by the researcher as the driver of digital OSH in the context of I4.0 to I5.0. These findings indicated that it is important to analyze and update occupational health and safety policies and procedures (e.g. Xu et al., 2021; Tender & Couto, 2021; Navarro Claro et al., 2025). Milea and Cioca (2024) emphasized that organizations review and update OSH policies and procedures for existing and new conditions. Thus, regulatory changes, corporate transformations, and technological advancements impact workplace policies, with flexible labor policies potentially undermining commitment to OSH programs (Goldstein et al., 2001). Lastly, the fifth driver is the human-centered approach. Lastly, the fifth aspect is the human-centered approach. There are some studies documenting the crucial role of a human-centered approach as a driver in addressing the issue of digital OSH. (e.g. Goździewska-Nowicka, 2024; Bucci et al., 2024; Davila-Gonzalez & Martin, 2024; Aksoy et al., 2023; Alzaabi, 2024). These findings emphasized the importance of prioritizing human needs, well-being, and collaboration in the transition toward I5.0. In the context of digital OSH, I5.0 adopts a human-centered production approach aimed at harmonizing the influence of technology with human existence and the corporate sphere. These shifts have the potential to enhance adaptability, efficiency, and sustainability within organizations; however, their adoption and acceptance may encounter a range of challenges. I5.0 is expected to drive profound transformations. Human–machine collaboration entails a close partnership in which machines handle repetitive tasks while humans contribute creativity and problem-solving skills. Customized production adapts manufacturing to individual customer needs, transcending the limitations of mass production (Aksoy et al., 2025).

Impact of Digital OSH on Worker Performance in anticipating the challenge of the I4.0 to I5.0 mediated by a Human-Centered Approach

The driver of digital OSH enhances worker performance in dealing with the challenge of the movement of I4.0 to I5.0 mediated by the human-centered approach. This is in line with the study by some researchers (e.g. Abdel-Basset et al., 2025; Musarat et al., 2022; Xu et al., 2021). While, there are three dimensions of worker performance, which are productivity, attitude and behavior, and work quality. The first dimension of worker performance is in terms of productivity. Researchers have revealed significant improvement in productivity by the adoption of digital OSH in the context of I4.0 aligned with a human-centric approach. These findings showed that digital OSH environments and tools contribute to increasing productivity when workers feel safe and comfortable at the workplace by synergizing human and machines collaborating (e.g. Gonzatti Feldman & Righi, 2021; Rojas et al., 2024; Aksoy et al., 2023). In the era of advanced technology integration, human safety is at the center of efforts to increase productivity. Thus, the integration of human and technologies provides substantial advantages, including enhanced worker safety and increased productivity (Milea & Cioca, 2024; Nguyen et al., 2024). Moreover, the second dimension of worker performance is in terms of attitude and behavior. Several studies emphasized the role of attitude and behavior in enhancing worker performance when practicing digital OSH (e.g. Brocal et al., 2019; Navarro Claro et al., 2025; Antonaci et al., 2024). As emphasized by González-Cañizalez et al. (2024), attitudes towards technology have been established as a mechanism for analyzing aspects that influence technology adoption. Therefore, a positive attitude toward digital OSH adoption contributes to enhancing worker performance in terms of I4.0 to I5.0. The third dimension of worker performance is in terms of work quality. A study by Rojas et al. (2024) showed that advanced digital technologies used in supporting OSH practices can significantly improve work efficiency. These findings can enhance worker performance mediated by implementing a human-centered approach. The study emphasized the importance of continuous improvement and collaboration to advance the adoption of technologies. It is clear that the I5.0 approach is an effort to restore human labor to its function in the workplace, where this condition requires humans and machines to collaborate to increase process efficiency by fully utilizing human intelligence and creativity through the way they interact through the use of the latest intelligent technology (Abdel-Basset et al., 2025).

Discussion

This study is a systematic literature review that aims to provide future direction on the important role of digital OSH on worker performance in addressing the issue of challenges in the transition era of I4.0 to I5.0. This study reviewed 35 articles to see the latest trends in literature related to the issue being studied. The number of studies related to digital OSH issues has increased steadily in 2024, which indicates a growing awareness of the importance of the role of digitalization in OSH programs. Furthermore, most of the studies were conducted in established countries such as Poland, Portugal, Sweden, Spain, the USA, and Romania. Meanwhile, from Asia, only conducted in countries with a more established level of economy or emerging economies, namely Saudi Arabia, Taiwan, Japan, Malaysia, and Egypt. This finding showed that there is still very little focus in countries in Asia and Africa on the importance of digitalization issues in OSH and its influence on worker performance in a dynamic era by adopting a new approach, namely the human-centered approach. Studies of OSH in developing countries are still very limited (Chen et al., 2020). This finding also revealed that most of the reviewed studies were conducted in multi-sector or various organizational contexts. This indicates that digital OSH is not only adopted by organizations vulnerable to risks and hazards, such as logging, oil, gas, mining, and transportation. Digital OSH adoption has been proven to be a crucial factor in improving worker performance across all sectors. In this term, current safety management processes are required to identify and develop alternative and/or advanced requirements and recommendations to ensure OSH practice is successful (Stefana et al., 2026). Further studies in the context of digital OSH comprehensively using mixed methods are needed for the future direction in the context of I4.0 to I5.0.

Table 1. List and Synthesis of Thematic Analysis

Author & Year	Technology Adoption	Focus of OSH	Challenge					Driver of Digital OSH				HCA	Impact on Worker Performance		
			MP	TS	TC	SS	SP	EP	WCE	SC	PP		PC	WB	WQ
Saniuk et al. (2024)	Technologies for composite, cooperating robots, etc.	Safe work environment in the I5.0 concept	X	X	X	X	X	X	X	X	X	X	X	X	X
Tender & Couto (2021)	Building Information Modelling (BIM)	OSH risk prevention		X	X	X	X	X			X		X	X	X
Ahn et al. (2019)	Wearable Sensing Technology Applications	Technologies for safety hazards and workers' health	X	X	X	X	X	X	X	X	X		X	X	X
Dodoo et al. (2024)	Wearable systems, AR/VR-based systems, AI-based systems, and Navigation-based systems	Digital innovations for safety and health management	X	X	X	X	X	X	X	X	X	X	X	X	X
Nilsson et al. (2025)	Algorithmic Management (AM)	OSH alongside operational efficiency.	X	X	X	X	X	X	X		X	X	X		X
Cagno et al. (2024)	Smartphones, cameras, and environmental cameras	Digital solutions to address hazardous situations	X	X	X	X	X	X	X	X	X	X	X	X	
González-Cañizalez et al. (2024)	IoT technology for data exchange	Safeguard worker safety and health	X	X		X		X		X		X	X	X	X
Niehaus et al. 2022)	AI-based systems	OSH and AI in the term "human in control."	X	X	X	X	X	X	X		X	X	X	X	X
Kabiesz et al. (2025)	Virtual reality, AI, & interactive simulations	Safety training and digital transformation	X	X		X		X	X		X	X	X	X	X
Neto et al. (2021)	SafetyCard-Performance Scorecard	Performance evaluation of OSH	X	X		X	X	X	X	X	X		X	X	X
Arana-Landín et al. (2023)	Additive manufacturing, AI, artificial vision, Big Data, IoT, robotics, cybersecurity	Occupational health and safety risks to improve performance	X	X	X	X	X	X	X		X	X	X	X	
Cheng et al. (2024)	Online platforms, Facebook communities, and social media	Digital platforms use data and algorithms	X			X	X		X		X		X		X

Author & Year	Technology Adoption	Focus of OSH	Challenge					Driver of Digital OSH				HCA	Impact on Worker Performance		
			MP	TS	TC	SS	SP	EP	WCE	SC	PP		PC	WB	WQ
MacEachen et al. (2025)	Software digital teaching	Digitalization and occupational health risks	X	X		X		X	X		X	X		X	
Asp et al. (2025)	A software robot with decision-making	Systematic Management of safety and health	X	X	X	X	X	X	X	X	X		X		X
Brocal et al. (2019)	IoT, cloud computing, and cognitive computing	Human-Machine Interactions (HMI) and Human-Robot Interaction (HRI)	X	X		X	X	X	X	X	X	X	X	X	X
Alzaabi (2024)	AI, IoT, sensors & digital twins	Risk assessment	X	X	X	X	X	X	X	X	X	X	X	X	X
Nowobilski et al. (2026)	Artificial intelligence (AI) algorithms	Risk-assessment systems and AI-based analytical tools	X	X		X	X	X		X	X		X	X	X
Liu et al. (2025)	Digital labor platforms	Platform work, work conditions and OSH	X	X		X	X	X	X		X			X	
Davila-Gonzalez & Martin (2024).	Human Digital Twin (HDT) cutting-edge technologies and advanced artificial intelligence (AI) techniques	Digital Twin framework and safety at work.	X	X		X	X	X	X		X	X	X	X	
Vitrano et al. (2024)	AI, Digital Twin, intelligent worker assistance system, etc.	Technological innovation guided by I5.0	X	X	X	X	X	X	X	X	X	X	X	X	X
Borges et al. (2021)	Human-Robot Collaboration System	Ergonomic design and Human-Robot Collaboration	X			X	X	X		X	X	X	X	X	
Bagir (2021)	BIM, AI systems and automation of work processes.	Risk management	X	X	X	X	X	X	X	X	X	X	X	X	X
Yassaee & Mettler (2019)	Digitized health-promoting systems	Prevention of occupational accidents	X	X		X	X	X	X	X			X	X	X
Muresan et al. (2024)	Digital Training of OSH	Digitalization of OSH activity	X	X		X	X	X		X				X	X

Author & Year	Technology Adoption	Focus of OSH	Challenge					Driver of Digital OSH				HCA	Impact on Worker Performance		
			MP	TS	TC	SS	SP	EP	WCE	SC	PP		PC	WB	WQ
Sasayama, et al. (2025)	Smartwatches and menstrual tracking apps	Digital health technology for health and well-being	X	X			X	X	X		X		X		X
Ferreira et al. (2021)	The Software Tool Safe Work Space (SWS)	Decision-making in the process of hazard analysis	X	X			X	X	X	X			X	X	X
Xu et al. (2021)	TechAI, BIM, Wearable sensors, IoT	Process and outcome of digitalisation	X	X		X	X	X	X	X	X		X	X	X
Park et al. (2023)	Digital Twin	A human-focused digital twin	X	X	X	X	X	X	X			X	X	X	X
Musarat et al. (2022)	Robotics & Automation, Augmented Reality & virtualization, BIM, Wireless Monitoring and sensors	Construction safety management	X	X	X	X		X	X		X	X	X	X	X
Carayon et al. (2015)	Systems Engineering Initiative for Patient Safety	Patient Safety and worker outcome	X	X	X	X	X	X	X	X	X		X	X	X
Iacob et al. (2026)	Telematics data & incident	Safety management in high-risk	X	X		X	X	X	X		X			X	X
Aljelaifi et al. (2025)	AI, IoT, robotics, and wearable devices	Safety in the digital age	X	X		X	X	X			X	X	X	X	
Ávila-Gutiérrez et al. (2022)	Cloud, IOT, big data, cognitive computing, open data, and other KETs	Occupational Safety and Health 5.0	X	X	X	X	X	X	X	X	X	X	X	X	X
Rojas et al. (2024)	Haptic gloves and virtual reality (VR) environments	Workplace safety and skills development	X	X		X	X	X	X	X	X	X	X		X
Abdel-Basset et al. (2025)	Cloud computing, robotics, blockchain, 5G technology, big data, drone technology, AI, IoT, and nanotechnology.	Human-centric, sustainable, and resilient industries.	X		X	X		X	X	X	X	X	X	X	X

Notes: MP = Mental & Physical Health; Technostress = TS; Technology Cost = TC; Social Support = SS; SP = System & Process; EE = Empowering; WCE = Working Condition & Work Environment; SC = Safety Culture; PP = Policy and Procedure; HCA = Human-Centric Approach; PC = Productivity; WB= Work Behavior; WQ = Work Quality

In addressing the research questions, this study first identified the digital OSH challenges in the transition from Industry 4.0 to Industry 5.0. These challenges include issues related to mental and physical health, technological stress, technological costs, social support, and organizational systems and processes. Second, the study highlighted several digital OSH drivers in the I4.0–I5.0 context, namely empowerment, working conditions and work environment, safety culture, and policy and procedures. Finally, the study demonstrated how these drivers influence worker performance—in terms of productivity, attitudes and behaviors, and work quality mediated by a human-centered approach (see Figure 6). These findings align with the work of Adel (2022) and Ávila-Gutiérrez et al. (2022), who similarly revealed the influence of digital OSH on worker performance through both challenges and drivers in the I4.0–I5.0 transition. Therefore, the drivers of digital OSH play a crucial role in enhancing workers' performance (Ibrahim et al., 2012), enabling organizations to anticipate and address the challenges of industrial evolution by applying the principles of Industry 4.0 and advancing toward Industry 5.0.

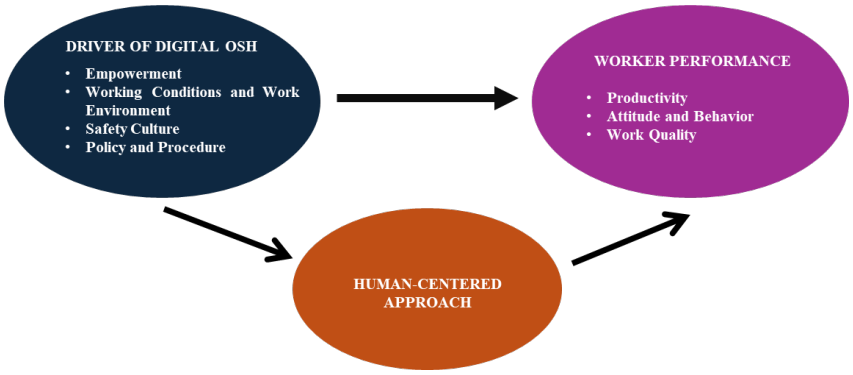

Figure 6. A Framework of Digital OSH on Worker Performance From I4.0 to I5.0

Conclusion

This study aimed to answer research questions regarding the challenges and drivers of digital OSH on worker performance in anticipating the movement of I4.0 to I5.0 by adopting the human-centered approach. The findings revealed that there has been an increase in publications on digital OSH issues. However, most of the studies were conducted in developed and emerging countries. The next finding showed that digital OSH has been applied generally in multi sectors, which indicated the awareness of the importance of digital OSH applied in all types of industry. Furthermore, digital OSH studies are mostly carried out using quantitative and qualitative approaches. An integrated study is needed to be able to provide a comprehensive understanding of digital OSH issues in terms of I4.0 to I5.0. Findings related to research questions were categorized into three digital OSH issues. Firstly, the findings show that there are several digital OSH challenges, namely mental and physical health, technological stress, technological costs, social support, and systems and processes. Secondly, several digital OSH drivers are empowerment, working conditions and work environment, safety culture, and policies and procedures. Thirdly, the findings showed that the implementation of digital OSH in addressing the challenges of I4.0 to I5.0 affects worker performance in three dimensions, namely productivity, attitude and behavior, and work quality. Digital OSH plays a significant role in improving worker performance in the era of industrial evolution by applying a human-centered approach as a mediator. Decision-makers have to focus on the adoption of digital OSH to enhance worker performance by adopting a human-centered approach as the cornerstone of I5.0. This study provided significant insight to identify challenges and drivers of digital OSH by presenting the mediation role of the human-centered approach. However, this study examined the impact of digital OSH on worker performance. Future studies are recommended to address constraints by examining the impact of digital OSH in I4.0 to I5.0 on other individual outcomes in the context of developing countries. Besides, it is necessary to integrate diverse methodological approaches in terms of qualitative and quantitative or mixed methods to present comprehensive findings on the digital OSH issue.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Acknowledgment

The authors would like to thank the team of Journal of Contemporary Management Studies (JCMS), Faculty of Management, Universiti Teknologi Malaysia (UTM), for their helpful feedback and support.

References

Abas, M. K. M., Yahaya, R. A., & Din, M. S. F. (2019). Digital Literacy and its Relationship with Employee Performance in the 4IR. *Journal of International Business, Economics and Entrepreneurship*, *4*(2), 29-29.

Abdullahi, M. S., Adieza, A., Arnaut, M., Nuhu, M. S., Ali, W., & Lawal Gwadabe, Z. (2025). Antecedents of employee performance through perceived organizational support: a moderating role of job satisfaction among employees of SMEs in an emerging economy. *Journal of Organizational Effectiveness: People and Performance*, *12*(3), 537-558.

Abdel-Basset, M., Mohamed, R., & Chang, V. (2025). A multi-criteria decision-making framework to evaluate the impact of industry 5.0 technologies: case study, lessons learned, challenges and future directions. *Information Systems Frontiers*, *27*(2), 791-821.

Adel, A. (2022). Future of industry 5.0 in society: human-centric solutions, challenges and prospective research areas. *Journal of cloud computing*, *11*(1), 40.

Ahn, C. R., Lee, S., Sun, C., Jebelli, H., Yang, K., & Choi, B. (2019). Wearable sensing technology applications in construction safety and health. *Journal of Construction Engineering and Management*, *145*(11), 03119007.

Aksoy, S., Demircioglu, P., Bogrekci, I., & Durakbasa, M. N. (2023, October). Enhancing human safety in production environments within the scope of Industry 5.0. In *The International Symposium for Production Research* (pp. 200-212). Cham: Springer Nature Switzerland.

Aljelaifi, A. A. M., Alsaedi, T. N. H., Alanazi, T. M. M., Al-Malki, S. A. Y., Alorabi, T. H. A., Alfayez, D. S., ... & Asiri, J. A. A. (2025). Safety in the digital age: investigating the impact of artificial intelligence and emerging technologies on occupational health and safety. *Lex localis*, *23*(s4), 980-988.

Alves, J., Lima, T. M., & Gaspar, P. D. (2023). *Is Industry 5.0 a Human-Centred Approach? A Systematic Review. Processes 2023, 11, 193*.

Alzaabi, A. S. (2024). Optimizing Safety in the Age of Industry 5.0: Mitigating Domino Effect.

Antonaci, F. G., Olivetti, E. C., Marcolin, F., Castiblanco Jimenez, I. A., Eynard, B., Vezzetti, E., & Moos, S. (2024). Workplace well-being in industry 5.0: a worker-centered systematic review. *Sensors*, *24*(17), 5473.

Arana-Landín, G., Laskurain-Iturbe, I., Iturrate, M., & Landeta-Manzano, B. (2023). Assessing the influence of industry 4.0 technologies on occupational health and safety. *Heliyon*, *9*(3).

Asp, A., Palm, K., & Håkansta, C. (2025). Occupational health and safety management when digitalizing public services: Local government manager experiences in Sweden. *WORK*, 10519815251403559.

Ávila-Gutiérrez, M. J., Suarez-Fernandez de Miranda, S., & Aguayo-González, F. (2022). Occupational safety and health 5.0—A model for multilevel strategic deployment aligned with the sustainable development goals of agenda 2030. *Sustainability*, *14*(11), 6741.

Bagir, M. (2021). Adoption of digital occupational safety and health technologies in the construction sector.

Baseman, C. M., Ryu, M., Swinger, N., Xu, K., Sherrill, A. M., & Arriaga, R. I. (2026, April). Human-centered Perspectives on a Clinical Decision Support System for Intensive Outpatient Veteran PTSD Care. In *Proceedings of the 2026 CHI Conference on Human Factors in Computing Systems* (pp. 1-17).

Beno, M. (2021, March). Office Evolution from Ancient Age to Digital Age (E-working). In *World Conference on Information Systems and Technologies* (pp. 182-192). Cham: Springer International Publishing.

Borges, G. D., Mattos, D. L. D., Cardoso, A., Gonçalves, H., Pombeiro, A., Colim, A., ... & Arezes, P. M. (2021). Simulating human-robot collaboration for improving ergonomics and productivity in an assembly workstation: A case study. In *Occupational and environmental safety and health III* (pp. 369-377).

Braun, V., & Clarke, V. (2023). Is thematic analysis used well in health psychology? A critical review of published research, with recommendations for quality practice and reporting. *Health Psychology Review*, *17*(4), 695-718.

Bucci, I., Fani, V., & Bandinelli, R. (2024). Towards human-centric manufacturing: Exploring the role of human digital twins in industry 5.0. *Sustainability*, *17*(1), 129.

Brocal, F., González, C., Komljenovic, D., Katina, P. F., & Sebastián, M. A. (2019). Emerging risk management in industry 4.0: An approach to improve organizational and human performance in the complex systems. *complexity*, *2019*(1), 2089763.

Bulboacă, E., Gheorghe, M., Nitoi, D., Enache, C., Borda, C., & Ţăpîrdea, A. (2024). Considerations Regarding The Application Of The Digitalisation In The Field Of Osh In Romania. *Fiability & Durability/Fiabilitate si Durabilitate*, *33*(1).

Cagno, E., Accordini, D., Neri, A., Negri, E., & Macchi, M. (2024). Digital solutions for workplace safety: An empirical study on their adoption in Italian metalworking SMEs. *Safety Science*, *177*, 106598.

Carayon, P., Schoofs Hundt, A., Karsh, B. T., Gurses, A. P., Alvarado, C. J., Smith, M., & Flatley Brennan, P. (2006). Work system design for patient safety: The SEIPS model. *Quality and Safety in Health Care, 15*(suppl 1), i50–i58. https://doi.org/10.1136/qshc.2005.015842

Chen, H., Hou, C., Zhang, L. & Li, S. 2020. Comparative study on the strands of research on the governance aljelaimodel of international occupational safety and health issues. Safety Science 122.

Cheng, Y., Cheng, W. J., Lin, R. T., Wang, Y. T., & Ko, J. J. R. (2024). Associations between labor control through digital platforms and workers' mental wellbeing: A survey of location-based platform workers in Taiwan. *Safety and Health at Work*, *15*(4), 419-426.

Darabont, D. C., & Bejinariu, C. (2024). Digitalization of the Occupational Health and Safety Management Processes. In *Digital Transformation: Exploring the Impact of Digital Transformation on Organizational Processes* (pp. 53-65). Cham: Springer Nature Switzerland

Davila-Gonzalez, S., & Martin, S. (2024). Human digital twin in industry 5.0: A holistic approach to worker safety and well-being through advanced AI and emotional analytics. *Sensors*, *24*(2), 655.

Demikhov, O., Opanasiuk, Y., Demikhova, N., & Merisalu, E. (2023). A digital transformation into occupational health and safety systems: a review of the best practices in Europe. *Agronomy Research*, *21*(2), 674-692.

Dodoo, J. E., Al-Samarraie, H., Alzahrani, A. I., Lonsdale, M., & Alalwan, N. (2024). Digital innovations for occupational safety: Empowering workers in hazardous environments. *Workplace health & safety*, *72*(3), 84-95.

da Silva, S. L. C., & Amaral, F. G. (2019). Critical factors of success and barriers to the implementation of occupational health and safety management systems: A systematic review of literature. *Safety science*, *117*, 123-132.

Dos Santos, C. N., Costa, A. C. F., Francisco, F. E., & De Oliveira, O. J. (2025). Driving the development and improvement of Occupational Health and Safety through Industry 4.0 technologies. *IEEE Access*.

Emery, R., Patlovich, S., & Delclos, G. (2023). Worker well-being: transforming from a traditional to a more holistic OSH program. *Professional Safety*, *68*(5), 23-25.

European Agency for Safety and Health at Work, “Digitalisation of Work,” [Online]. Available: https://osha.europa.eu/en/themes/digitalisation-work

Ferreira, A. R., Soares, Â., Sousa, B., Brito, M., Gonçalves, M. A., Ferreira, L. P., & Silva, F. J. (2021). SWS—A decision-making tool to support occupational safety. In *Occupational and Environmental Safety and Health III* (pp. 13-24). Cham: Springer International Publishing.

Frey, C. B., & Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerisation?. *Technological forecasting and social change*, *114*, 254-280.
Goldstein, G., Helmer, R., & Fingerhut, M. (2001). The WHO global strategy on occupational health and safety. *African Newsletter on Occupational Health and Safety*, *11*(3), 56-60.

Gonzatti Feldman, I. A., & Righi, A. W. (2021). Application of ErgoVSM to Improve Performance and Occupational Health and Safety Conditions in a Medication Dispensing System. In *Occupational and Environmental Safety and Health III* (pp. 389-398).

González-Cañizalez, Y., Silva-Barreto, J., Manrique-Suárez, R., & Rodríguez, B. (2024). Technologies for safety and health management in large companies in Ecuador: A worker-centric exploration from technology adoption attitudes. *Journal of applied research and technology*, *22*(6), 897-906.

Goździewska-Nowicka, A. (2024). Health and safety management in the era of building Society 5.0. *Zeszyty Naukowe. Organizacja i Zarządzanie/Politechnika Śląska*, (192), 313-326.

Hiba, J. C. (2002). Ten safety and health challenges for the twenty-first century. *Labour education*, 68-75.

Holzer, M. (2022). Protect the protectors: a qualitative study on OSH in conjunction with unwanted side effects for the work performance of frontline police officers. *International Journal of Occupational Safety and Ergonomics*, *28*(3), 1967-1972.

Iacob, A., Chivu, O. R., Trifu, A., Cana, A., & Bibis, A. Occupational Health and Safety training using online platforms in road transport-a case study. *Journal of Research and Innovation for Sustainable Society*, 20

Ibrahim, M., Karollah, B., Juned, V., & Yunus, M. (2022). The effect of transformational leadership, work motivation and culture on millennial generation employees performance of the manufacturing industry in the digital era. *Frontiers in Psychology*, *13*, 908966.

Kabiesz, P., Płaza, G., & Jamil, T. (2025). Modern Technologies in Occupational Health and Safety Training: An Analysis of Education, Innovation, and Sustainable Work Practices in Industry. *Sustainability*, *17*(16), 7305.

Karakhan, A. A., Nnaji, C. A., & Jin, Z. (2021). How technology can improve OSH management in construction. *Professional Safety*, *66*(12), 18-26.

Kastelli, I., Dimas, P., Stamopoulos, D., & Tsakanikas, A. (2024). Linking digital capacity to innovation performance: The mediating role of absorptive capacity. *Journal of the Knowledge Economy*, *15*(1), 238-272.

Koh, D., & Tan, A. (2024). Applications and impact of Industry 4.0: Technological innovations in occupational safety and health. *Safety and Health at Work*, *15*(4), 379-381.

Korte, P., Kobert, M., & Süße, T. (2024, September). Digital leadership from the perspective of organization 5.0: an analysis of key action fields towards green, resilient, and human-centered digitalization. In *Working Conference on Virtual Enterprises* (pp. 365-379).

Lamm, F., Massey, C., & Perry, M. (2007). Is there a link between workplace health and safety and firm performance and productivity?. *New Zealand Journal of Employment Relations*, *32*(1), 75-90.

León, O., Kanat, B., Puente, J., & Fernandez, I. (2024, July). Human-centered Industry 5.0: enhancing supply chain resilience and sustainable practices. In *World Congress in Computer Science, Computer Engineering & Applied Computing* (pp. 418-422). Cham: Springer Nature Switzerland.

Liu, W., Chang, W., Guo, J., Chen, S., & Wang, H. J. (2025). Electronic performance monitoring and job crafting: a psychological ownership perspective. *Journal of Digital Management*, *1*(1), 9.

Longo, F., Padovano, A., & Umbrello, S. (2020). *Value-Oriented and Ethical Technology Engineering in Industry 5.0*. Applied Sciences, 10(12), 4182.

MacEachen, E., Whitson, J., Premji, S., Aurini, J., Hopwood, P., Miller, M., ... & Sultana, I. (2025). Unequal occupational conditions when work turns digital: The case of schoolteachers. *New Solutions: A Journal of Environmental and Occupational Health Policy*, *35*(3), 283-291.

Milea, A., & Cioca, L. I. (2024). Work evolution and safety and health at work in Industry 4.0/Industry 5.0. In *MATEC Web of Conferences* (Vol. 389, p. 00074). EDP Sciences.

Min, J., Kim, Y., Lee, S., Jang, T. W., Kim, I., & Song, J. (2019). The fourth industrial revolution and its impact on occupational health and safety, worker's compensation and labor conditions. *Safety and health at work*, *10*(4), 400-408.

Mohammad, A. M., Menhat, M., Shafi, S., Hussein, A. H. M. A., Al-Mubaideen, M. A., & Alshaketheep, K. (2025). Trends in employee performance: A comprehensive review and bibliometric analysis using Scopus and WOS. *SA Journal of Human Resource Management*, *23*, 2887.

Mourtzis, D., Angelopoulos, J., & Panopoulos, N. (2023). The future of the human–machine interface (HMI) in society 5.0. *Future Internet*, *15*(5), 162.

Mourtzis, D. (2024). Challenges and opportunities of the transition from Industry 4.0 to Industry 5.0. *Manufacturing from Industry 4.0 to Industry 5.0*, 97-131.

Moraru, R. I. (2024). Challenges and opportunities in occupational health and safety digitalization. *Digital Transformation: Technology, Tools, and Studies*, 189-213.

Mohamed Shaffril, H.A., Samsuddin, S.F. & Abu Samah, A. 2021. The ABC of systematic literature review: The basic methodological guidance for beginners. Quality and Quantity 55(4): 1319–1346.

Mullaney, T., Nyholm, T., & Edvardsson, D. (2011). Wellbeing in healthcare environments: a human-centered design research approach to improving the cancer patient experience during radiation therapy. In *Design 4 Health* (pp. 255-265).

Müller, J. M., Kiel, D., & Voigt, K. I. (2019). Assessing the barriers to Industry 4.0 implementation from a workers' perspective. *IFAC-PapersOnLine, 52*(13), 2189–2194.

Mureșan, Petru-Iulian, Ioan Milosan, Mariela Pavalache-Ilie, Camelia Gabor, and Gheorghe Oancea. "Evaluation of the training process of health and safety at work in industry through digitalization—case study: Position in organization." *Applied Sciences* 14, no. 18 (2024): 8502.

Musarat, M. A., Alaloul, W. S., Irfan, M., Sreenivasan, P., & Rabbani, M. B. A. (2022). Health and safety improvement through Industrial Revolution 4.0: Malaysian construction industry case. *Sustainability*, *15*(1), 201.

Nahavandi, S. (2019). Industry 5.0—A human-centric solution. *Sustainability*, *11*(16), 4371.

Navarro Claro, G. T., Bayona Soto, J. A., & Arévalo Ascanio, J. G. (2025). Impact of the occupational health and safety management system (OHSMS) on human talent management and organizational performance in the construction sector. *Frontiers in Built Environment*, *11*, 1618356.

Neto, H. V., Arezes, P. M., & Junior, B. B. (2021). Cultural and Technical Adaptation of SafetyCard to the Brazilian Legislative and Organizational Context. In *Occupational and Environmental Safety and Health III* (pp. 3-12). Cham: Springer International Publishing

Niehaus, S., Hartwig, M., Rosen, P. H., & Wischniewski, S. (2022). An occupational safety and health perspective on human in control and AI. *Frontiers in Artificial Intelligence*, *5*, 868382.

Nilsson, K. H., Matilla-Santander, N., Lee, M. K., Brulin, E., Bodin, T., & Håkansta, C. (2025). Algorithmic management and occupational health: A comparative case study of organizational practices in logistics. *Safety Science*, *187*.

Nguyen, T., Nguyen, D. H., Nguyen, Q. T., Tran, K. D., & Tran, K. P. (2024). Human-Centered Edge AI and Wearable Technology for Workplace Health and Safety in Industry 5.0. In *Artificial Intelligence for Safety and Reliability Engineering: Methods, Applications, and Challenges* (pp. 171-183). Cham: Springer Nature Switzerland.

Nowobilski, T., Woźniak, Z., & Hoła, A. (2026). The Use of Digital Tools by Occupational Health and Safety (OHS) Specialists in the Polish Construction Sector. *Applied Sciences*, *16*(2), 888.

Oeij, P., Lenaerts, K., Dhondt, S., Van Dijk, W., Schartinger, D., Sorko, S., & Warhurst, C. (2024). A conceptual framework for workforce skills for industry 5.0: Implications for research, policy and practice. *Journal of Innovation Management*, *12*(1), 205-233.

Ozmen Garibay, O., Winslow, B., Andolina, S., Antona, M., Bodenschatz, A., Coursaris, C., ... & Xu, W. (2023). Six human-centered artificial intelligence grand challenges. *International Journal of Human–Computer Interaction*, *39*(3), 391-437.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *bmj*, *372*.

Palumbo, R., & Cavallone, M. (2024). Is work digitalization without risk? Unveiling the psycho-social hazards of digitalization in the education and healthcare workplace. *Technology Analysis & Strategic Management*, *36*(6), 1136-1149.

Papacharalampopoulos, A., Karagianni, O. M., Fedeli, M., Lackner, P., & Stavropoulos, P. (2026). Cyber-Physical Human Production Systems in Industry 5.0: a training case study of knowledge transfer in high-end-tech industry. *Procedia CIRP*, *139*, 425-432.

Park, J. S., Lee, D. G., Jimenez, J. A., Lee, S. J., & Kim, J. W. (2023). Human-focused digital twin applications for occupational safety and health in workplaces: a brief survey and research directions. *Applied saniuSciences*, *13*(7), 4598

Pasman, H. J., & Behie, S. W. (2024). The evolution to Industry 5.0/Safety 5.0, the developments in society, and implications for industry management. *Journal of Safety and Sustainability*, *1*(4), 202-211.

Polak-Sopinska, A., Wisniewski, Z., Walaszczyk, A., Maczewska, A., & Sopinski, P. (2019, June). Impact of industry 4.0 on occupational health and safety. In *International conference on applied human factors and ergonomics* (pp. 40-52). Cham: Springer International Publishing.

Queirós, J., Faria, H., & Correia, A. (2025). Emerging Technologies in Occupational Safety and Health: Identification, Use and Perception by OSH Professionals in Portugal. *Occupational and Environmental Safety and Health VI: Volume 2: Biomechanics, Occupational Psychosociology and New Trends*, 545-560.

Rojas, M., Maldonado-Romo, J., Mendez, J. I., Ponce, P., & Molina, A. (2024). Smart interfaces to assist the operator in the context of industry 4.0 with a 5S human-centric approach. *Wearable Technologies*, *5*, e24

Saniuk, S., Grabowska, S., & Thibbotuwawa, A. (2024). Challenges of industrial systems in terms of the crucial role of humans in the Industry 5.0 environment. *Production Engineering Archives*, *30*.

Sasayama, K., Saso, T., Egawa, Y., Nishimura, E., Ota, E., Tachimori, H., ... & Saito, E. (2025). Working women's perceptions and expectations of digital health tools for personal health management: A qualitative study. *Digital Health*, *11*, 20552076251379747

Schwab, K. (2016). The Fourth Industrial Revolution. Geneva: World Economic Forum

Stefana, E., Di Gravio, G., & Patriarca, R. (2026). Editorial on Safety 5.0: Safety management in sustainable, human-centric, and resilient industrial systems. *Journal of Safety and Sustainability*.

Tender, M., Couto, J. P., & Fuller, P. (2021). Integrating Occupational Health and Safety Data Digitally Using Building Information Modelling—Uses of BIM for OHS Management. In *Occupational and Environmental Safety and Health III* (pp. 85-96). Cham: Springer International Publishing.

Villani, V., Pini, F., Leali, F., & Secchi, C. (2018). Survey on human–robot collaboration in industrial settings: Safety, intuitive interfaces and applications. *Mechatronics, 55*, 248–266. https://doi.org/10.1016/j.mechatronics.2018.02.009

Vitrano, G., Micheli, G. J., Marazzini, F., Panio, V., Castaldo, A., Marrocco, A., ... & Marinaccio, A. (2024). Examining the Complex Interaction Among Technological Innovation, Company Performance, and Occupational Safety and Health: A Mixed-Methods Study. *International Journal of Environmental Research and Public Health*, *21*(10), 1368.

Vuori, V., Helander, N., & Okkonen, J. (2019). Digitalization in knowledge work: the dream of enhanced performance. *Cognition, Technology & Work*, *21*(2), 237-252.

Xu, J., Duryan, M., & Smyth, H. (2021, September). Digitalisation for Occupational Health and Safety in Construction: A Path to High Reliability Organising?. International Council for Research and Innovation in Building and Construction (Conseil International du Bâtiment).

Yassaee, M., & Mettler, T. (2019). Digital occupational health systems: What do employees think about it?. *Information Systems Frontiers*, *21*(4), 909-924.Zairul, M. (2025). Mastering thematic analysis: A step-by-step guide for beginners with tips for systematic analysis using ATLAS. ti 25. *International Journal of Qualitative Methods*, *24*, 16094069251384401.

Zorzenon, R., Lizarelli, F. L., & Braatz, D. (2025). The impact of the internet of things on health and safety performance at work: An empirical study of Brazilian companies. *Safety Science*, *187*, 106866.