
International
Labour
Organization
Global report
revolutionizing
health and safety:
The role of AI and
digitalization at work.

Global report

revolutionizing *health and safety:*

The role of **AI and digitalization** at work.

▶ World Day for Safety and Health at Work 2025

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List of abbreviations

AI	Artificial intelligence
AM	Algorithmic management
AR	Augmented reality
COBOT	Collaborative robot
EU	European Union
ILO	International Labour Organization
IOE	International Organisation of Employers
IoT	Internet of Things
NIOSH	US National Institute for Occupational Safety and Health
OECD	Organisation for Economic Co-operation and Development
OSH	Occupational safety and health
PPE	Personal protective equipment
SMEs	Small and medium-sized enterprises
UAV	Unmanned aerial vehicle
VR	Virtual reality
WHO	World Health Organization
XR	Extended reality

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Executive summary

How is digitalization transforming safety and health at work?

Digitalization and automation are impacting millions of jobs worldwide, presenting unprecedented opportunities to enhance occupational safety and health. Automation and smart monitoring systems can reduce hazardous exposures, prevent workplace injuries and improve overall working conditions. Nevertheless, proactive policies are needed to address the potential risks.

- **Automation and advanced robotics** are streamlining physical and cognitive tasks, reducing exposure to hazardous environments and repetitive strain injuries. Potential associated concerns to address may include mechanical failures, in addition to ergonomic, physical (such as noise) and psychosocial risks.
- **Smart OSH tools and monitoring systems**, including AI-powered sensors and wearable devices, enable real-time hazard detection, predictive risk assessments and proactive OSH management. Ensuring usability, proper fit for diverse workers, privacy protection and the prevention of stress from continuous monitoring are key.
- **Extended and virtual reality** are transforming worker training with immersive simulations for hazard recognition and emergency response. However, potential risks such as blocked visibility, balance issues, visual strain and cognitive overload must be managed.
- **Algorithmic management of work** uses AI-driven or programmed systems to coordinate labour in an organization, optimizing task allocation, improving engagement and work-life balance, and addressing skill gaps. However, potential risks such as excessive surveillance and work intensification must be controlled and addressed.
- **Changing work arrangements** through digitalization, including telework and digital labour platforms, offer flexibility but could pose both physical and psychosocial OSH challenges.

To maximize the benefits of digitalization in OSH while mitigating risks, a proactive, evidence-informed and participatory approach is essential. This requires the active involvement of governments, employers and workers, along with OSH professionals and other stakeholders to ensure that digital transformation strengthens, rather than compromises safety and health at work.

How do we ensure OSH in the digital era?

Existing OSH frameworks, including ILO OSH standards, remain essential for safeguarding the right to a safe and healthy working environment in the digital era.

Recognizing the interdisciplinary nature of OSH and digitalization, some countries are mainstreaming OSH considerations into broader policies on AI and digital transition. On the other hand, some countries are integrating digitalization into OSH policy frameworks to enhance risk prevention, monitoring and worker protection.

Countries are also beginning to review and adapt their legal frameworks. Key areas of legal development include updating robotics safety regulations and human-robot interaction protocols to mitigate risks in collaborative work environments. They also entail establishing the right to disconnect to prevent digital burnout and overwork. Additionally, OSH protections are being expanded to cover remote and platform work, acknowledging the evolving nature of work.

Complementing these policy measures, voluntary standards and guidance, awareness campaigns, training initiatives and research programmes are playing a crucial role to guide businesses and equip workers with the necessary skills to use new technologies safely. However, further research is needed to better understand the long-term OSH impacts of digital technologies and ensure informed implementation.

At the workplace level, regular risk assessment and management remain essential to proactively addressing emerging digital risks. This involves regularly evaluating risks associated with new technologies, implementing preventive measures aligned with the OSH hierarchy of controls, and continuously adapting OSH policies to remain effective as technologies evolve, incorporating worker feedback and the latest OSH advancements.

Digital tools like AI-driven analytics, real-time monitoring, and predictive modelling can enhance risk assessments and OSH strategies but must complement - not replace - human judgement in OSH practices.

Workers and their representatives should be actively involved at all stages of digital technology implementation, including design, operation, and monitoring, ensuring technologies enhance rather than undermine safety and health at work.

By adopting a collaborative, forward-looking, and worker-centred approach, stakeholders can ensure digital innovation leads to safer, healthier, and more sustainable workplaces, benefiting everyone involved.

About This Report

Based on an in-depth desk review, key informant interviews and a review of policy and practice, this report explores the changes digital technologies are bringing to safety and health at work and the need to ensure that these changes do not result in potential risk.

By providing policy insights, practices and real-world case studies, this report serves as a resource for governments, employers, workers and OSH experts to navigate the evolving landscape of digital safety at work.

The first part of the report examines how automation and advanced robotics, smart OSH tools and monitoring systems, extended reality and virtual reality, algorithmic management of work and changing work arrangements are reshaping workplace safety and health, considering both opportunities and potential risks.

The second part explores global, regional, and national policies that govern OSH in digitalized workplaces, highlighting regulatory gaps and policy responses. It also discusses risk assessment, worker participation and preventive strategies for integrating digital tools safely and effectively at the workplace level.

Finally, the concluding key takeaways summarize the major findings, emphasizing the critical actions needed to ensure a responsible, inclusive and worker-centred digital transition.

1

How digitalization is transforming safety and health at work

Digitalization[1] is reshaping the world of work, introducing innovative practices, fostering new industries and reshaping both physical and psychosocial working environments.

Artificial intelligence (AI)[2] and digital tools offer businesses significant opportunities to enhance occupational safety and health (OSH). When effectively designed and implemented, these technologies help mitigate occupational risks, reduce workplace accidents and diseases and improve efficiency, productivity and overall performance (Sun et al. 2022). One of the key benefits of digitalization is removing workers from hazardous environments and exposures, including chemicals, extreme temperatures, radiation, confined spaces and high-risk machinery. It also optimizes work organization, streamlining processes, automating repetitive and physically demanding tasks and improving workload distribution, reducing both physical and mental strain (EU-OSHA 2019). AI-driven systems and tools enhance workplace safety by identifying hazards, monitoring environmental conditions and predicting equipment failures. Additionally, digitalization supports career development through tailored upskilling and reskilling opportunities, ensuring workers can adapt to evolving job demands and be adequately prepared to address new OSH risks (EU-OSHA 2019). However, it is important to note that the benefits of digitalization are not universally shared.[3]

While digitalization offers numerous benefits for OSH, it may introduce significant risks that can be prevented and must be carefully managed. Human-robot interaction failures, ergonomic challenges and exposure to noise and vibration hazards are some of the potential risks associated with digital technologies (EU-OSHA 2009). Wearable and smart devices, if improperly designed, may lead to physical strain, while unmanned aerial vehicles (UAVs), such as drones, and head-mounted displays can pose risks of injury, loss of balance and visual hazards. Technological advancements can also lead to work intensification, job insecurity and "technostress[4]", as workers face increasing pressure to adapt to rapidly evolving tools and processes (ILO 2022). The blurring of work-life boundaries due to mobile and online work can contribute to burnout, while intrusive surveillance and constant monitoring may infringe on privacy and reduce job autonomy (ILO 2018). As workers spend more time using digital tools, they may be increasingly exposed to cyberbullying. AI-driven decision-making risks task fragmentation, loss of job satisfaction and bias, potentially marginalizing certain groups and exacerbating inequalities in the workplace.

Addressing these challenges requires a proactive approach to OSH, ensuring that digital transformation enhances rather than compromises worker safety and well-being (Gonzalez Vazquez et al. 2024).

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1 According to the ILO, digitalization is understood in broad terms to mean the application of digital technologies, and thus digitized information or data, in the economy and society (GB.350: Working Party on the Social Dimension of Globalization. Challenges and opportunities of digitalization). In the world of work, digitalization entails the transformation of organizational structures and processes with the aim of improving efficiency, revenues and resilience. Such application reshapes the organization of work and thus has consequences for the amount and type of employment offered as well as working conditions and labour protection.

2 AI is a core component of digitalization. AI systems may be purely software-based or embedded in physical devices (High-Level Expert Group on Artificial Intelligence 2019). They can complement and support human tasks, replace existing roles or create new ones (Selenko et al. 2022).

3 Disparities arise due to infrastructure limitations, unequal access to digital skills and implicit or explicit discrimination based on factors such as location, ethnicity, religion and gender (Graham et al. 2017). Small and medium-sized enterprises, particularly in developing countries, face challenges in adopting digital tools due to resource constraints (IMF 2024a). As such, technology should not be seen as a one-size-fits-all solution. Its effectiveness depends on the context in which it is implemented and the extent to which workers are involved in shaping its design, operation and control.

4 https://www.emerald.com/insight/content/doi/10.1108/intr-03-2022-0214/full/html

This chapter explores the impact of digitalization on OSH, grouping technologies and work process into five categories: **automation and advanced robotics; smart OSH tools and monitoring systems; extended and virtual reality; algorithmic management of work and changing work arrangements through digitalization.** For each of these technologies and processes, the research highlights how they can enhance safety and health at work by mitigating physical, organizational and psychosocial risks in addition to examining the potential associated risks. The findings emphasize the need for a balanced and proactive approach to ensure safe and healthy working environments for all.

1.1 Automation and advanced robotics

Automation and advanced robotics[5] are driving profound changes in workplace safety and health, introducing innovative ways to enhance efficiency and reduce risks across industries (EU-OSHA 2024a; Petersen et al. 2023). These technologies automate both physical tasks, such as assembly, material handling and hazardous operations, and cognitive processes, including decision-making and data analysis, redefining how work is performed, monitored and managed (Wang 2019; Chen et al. 2023).

Advanced robotics refers to technologies designed to perform tasks requiring high precision, adaptability and autonomy that can enhance productivity and workplace safety by reducing workers' exposure to physically demanding or hazardous activities. These systems include industrial robots, such as robotic arms used for repetitive and hazardous tasks, as well as modern innovations such as autonomous mobile robots, drones, exoskeletons and collaborative robots ("cobots") working alongside humans to enhance efficiency and safety (EU-OSHA 2022b). Robots are used in a variety of sectors. For example, they handle hazardous and repetitive tasks in manufacturing, assist with diagnostics and surgeries in healthcare, enhance precision in agriculture, optimize logistics, support disaster recovery and perform critical military operations like reconnaissance and bomb disposal (EU-OSHA 2022b).

AI plays a central role in automating both cognitive and physical tasks, enabling applications such as health monitoring, autonomous driving systems, chatbots and industrial robots (EU-OSHA 2022f). It also powers functions such as customer service, translation and cash register operations, reducing human workloads and enhancing productivity (Petersen et al. 2023; Babashahi et al. 2024). These advancements are transforming almost every industry, even those traditionally considered as low-tech (ILO 2023).

The global impact of automation and AI on jobs is significant. The ILO (2023) estimates that automation could at least partially replace nearly 75 million jobs worldwide, while AI could augment 427 million jobs, across various sectors. The effects vary by region and demographics. Europe and North America, with diversified labour markets, have the highest exposure to automation (UN/ILO 2024), while Asia, Africa and Latin America face lower exposure due to the prominence of agriculture and informal sectors less impacted by generative AI (UN/ILO 2024). In China, AI technologies such as large language models may displace higher-paying, experience-intensive jobs, reversing previous labour demand trends (Chen et al. 2023).

Women are disproportionately affected by generative AI, with their exposure to automation being more than double that of men in most regions (UN/ILO 2024). Business process outsourcing, such as call centre work, a significant source of formal, relatively well-paid employment for women in several developing countries, is particularly at risk (UN/ILO 2024).

[5] Advanced robotics, a term that emerged in the 1980s, refers to robots equipped with sophisticated software and hardware capable of making intelligent decisions, unlike traditional machines (Robotnik 2022). The integration of AI technologies enables these robots to interact independently with their environment and perform complex tasks (Licardo et al. 2024).

1.1.1 How automation and robotics are improving safety and health at work

▶ Removing workers from high-risk environments and exposures

Robots are increasingly used to replace workers in dangerous tasks and high-risk environments, often referred to as "3D jobs" (dirty, dangerous and demeaning). In mining, construction, and manufacturing, they enable workers to supervise hazardous operations remotely, reducing exposure to risks such as carcinogenic welding fumes, bomb disposal and chemical spills (Robots.com 2017; CCOHS 2022b). In disaster recovery, ground, aerial and marine robots withstand extreme conditions such as high heat, moisture and radiation (Guizzo 2023; Soori et al. 2023). Similarly, in healthcare, robots reduce worker exposure to radiation during MRI scans and X-rays, assist with ultraviolet disinfection and, during COVID-19, minimized risks by handling patient transport and sanitation (Deo and Anjankar 2023; Mehta et al. 2023; Su et al. 2021). Robots also help in extreme temperature environments, such as operating furnaces in manufacturing or working in freezing oil fields (A3 Marketing Team, 2019).

▶ Five Dangerous Tasks Robots Can Perform Safely (Owen-Hill 2022)

- **Lifting very heavy and medium-heavy objects:** Robots can lift very heavy objects that are beyond human capacity. They can also lift lighter objects whose repeated daily lifting could pose a risk to human workers over time.
- **Stirring 2,000 degrees Celsius molten metal:** Robots can be used for "furnace tapping", where molten metal is stirred to remove a waste by-product called slag. This process requires workers to agitate metal with a long oxygen lance, potentially drenching the worker in a cascade of burning sparks. Robot arms can be wrapped in a heat-proof covering that allows them to withstand the high-temperature environment.
- **Collecting and packaging radioactive waste:** Handling radioactive materials poses inherent risks to human health. For tasks such as handling radioactive waste from nuclear power plants, robotics offer the safest and most viable solution.
- **Working in contaminated and dusty environments:** Robots can improve worker safety in unsafe working environments, such as those contaminated with dust or toxic chemicals.
- **Repeated physical motions:** Robots are well-suited for performing repetitive tasks that could pose significant risks to human workers from serious musculoskeletal disorders.

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Unmanned aerial vehicles (UAVs), such as autonomous drones, can be used to perform operations autonomously in areas where human intervention is dangerous, difficult, expensive or physically intensive (Kanellakis and Nikolakopoulos 2017). They can assist in emergencies, collect data and undertake hazardous tasks for humans, such as working at height or in extreme environments, including hazardous or toxic ones (HSE Network 2020). In agriculture, drones are increasingly used for pesticide application, reducing operator exposure to harmful chemicals which have been linked to cancers, poisoning and neurological damage (ILO 2021b). For example, in China, drones have been widely deployed to spray pesticides, with over 200,000 drones carrying out operations in 2021 (Ozkan 2024). However, effective training for drone operators is crucial to prevent harm to workers and the environment (Amarasinghe et al. 2019; Yan et al. 2021; Kuster et al. 2023).

Application Of Drone Systems for Spraying Pesticides in Advanced Agriculture

Farmers are at risk of adverse health effects when spraying pesticides manually onto crop fields. The use of drones for spraying pesticides is a promising alternative to manual spraying. A review by Borikar et al. (2022) explored the latest technological advances and applications in hardware, flight controller and electronic speed controller, smart agricultural sensors and spraying systems. Key advancements in drone systems include:

- The use of multispectral cameras mounted on drones for crop monitoring.
- GPS-enabled drone spraying system that applies pesticides to infected areas in real-time, triggered by the camera capturing images.
- Different types of nozzles are applied, leading to specific sprinkling speeds which are controlled via smartphone.
- Auto-control of the quantity of pesticides according to the speed of the drone and use of AI for smart drone path control.
- Overall, the study found that drones can complete pesticide spraying tasks quickly and accurately, without posing health risks to humans.

▶ Supporting workers to reduce physical strain

Robotic systems are increasingly used to reduce repetitive or strenuous tasks across various sectors. These technologies help alleviate exposure to strong forces, awkward postures and repetitive movements – key factors linked to musculoskeletal disorders (EU-OSHA 2021; 2022a). By taking over repetitive, manual and mentally unstimulating tasks, robots allow workers to focus their energy on more strategic and creative aspects of work (Timbó 2023).

Exoskeletons are wearable robotics used to enhance, augment or assist the user's posture, motion or physical activity in jobs involving manual work or physical effort (CCOHS 2022a). They are increasingly used in industries such as construction, manufacturing, agriculture and healthcare (Flor-Unda et al. 2023; Ekso Bionics 2022). Studies show that exoskeletons significantly reduce muscle activity and strain, particularly in the back and legs, during material handling tasks (Bär et al. 2021; Park et al. 2022). For example, whole-body powered exoskeletons have been shown to reduce back muscle activity by up to 53 per cent and leg strain by 63 per cent, lowering injury risks and contributing to long-term savings in healthcare and productivity (Zelik et al. 2022; Kirpestein et al. n.d.). By minimizing physical strain and fatigue, exoskeletons can also alleviate stress and improve overall psychological well-being (Vallée 2024).

Robotics in healthcare – enhancing safety and reducing risks

From diagnostics and disinfection to surgery and patient assistance, robotics is playing a crucial role in protecting healthcare professionals.

Robots help safeguard workers by reducing radiation exposure during MRI scans and X-rays and minimizing infection risks through patient transport, sanitation and autonomous disease testing (Su et al. 2021; Deo and Anjankar 2023). For example, during COVID-19, Haddadin et al. (2024) developed an autonomous swab robot that safely performed screenings without human intervention. Tested on 52 patients in Germany, it demonstrated high accuracy, strong acceptance rates and the ability to conduct up to 300 tests per day per robot. Automated or robot-assisted swabbing may significantly enhance testing capacity while protecting staff (Yang et al. 2020).

In physically demanding roles, robots and exoskeletons help reduce physical strain and injury risks, particularly in nursing, elderly care and surgery. By assisting with patient movement, they ease the burden on caregivers and lower the risk of musculoskeletal injuries (Richarz et al. 2023; Persson et al. 2021). This technology also helps prevent burnout and stress, particularly in high-demand settings (O'Connor 2021).

Robotic surgery has revolutionized surgical procedures, enhancing precision, reducing workload and improving ergonomics compared to traditional laparoscopic and open surgery (Wee et al. 2020). However, neck, shoulder and back discomfort remain a challenge due to console design, highlighting the need for better ergonomic practices and formal training to minimize strain (Patel et al. 2023).

While robots can support healthcare workers by reducing risks and improving efficiency, they cannot replace human roles that require empathy, judgement and decision-making (Witkowski et al. 2024).

▶ Reducing repetitive and boring tasks

Automation and AI systems can eliminate repetitive and routine kinds of clerical or administrative tasks, such as form-filling and processing applications or legal documents (EU-OSHA 2022e). In customer service, for example, AI-driven chatbots and virtual assistants can handle complex enquiries, reducing the workload for human representatives (Babashahi et al. 2024). A recent study found that AI could help automate around 84 per cent of repetitive transactions across 400 government services in the UK (The Alan Turing Institute 2024). In healthcare, interactive robots ease workloads by collecting vital signs and patient data, allowing professionals to focus on complex tasks and patient care (Ragno et al. 2023). In education, AI-powered tools can be used for grading assignments, tracking attendance and scheduling meetings, allowing educators to concentrate more on higher-level teaching and less on paperwork (Jose 2023).

AI systems can relieve workers from having to plan and perform certain tasks, and in some cases reduce their need to anticipate processes or expend energy mentally monitoring their safety during procedures (EU-OSHA 2023a). A survey of 34,000 workers in 18 countries worldwide found that that 64 per cent of participants agreed that AI and automation technology helped reduce both workload and stress and for those workers who enjoyed low-stress workplaces, 72 per cent attributed this in part to access to tools and technology to work productively (McKendrick 2019).

Automation and AI systems have the potential to make work more meaningful for some workers, for example by enhancing human learning, skills and development and allowing more control and power for workers through greater access to information (Bankins and Formosa 2023). Job control tends to increase when autonomous systems are introduced to a workplace, as they increase the workers' ability for time allocation (EU-OSHA 2022a). For some workers, the automation of tasks can move them into higher, supervisory jobs with more impactful decision-making (EU-OSHA 2023a). A study found that 92 per cent of surveyed knowledge workers[6] agreed that automation improved their lives in the workplace (Zapier 2021).

[6] Knowledge workers include, for example, high-level workers who apply theoretical and analytical knowledge, acquired through formal training, to develop products and services" to assist the general reader.

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1.1.2 Potential risks associated with automation and advanced robotics

When introducing robots or exoskeletons into the workplace, there are several risks that must be carefully considered and managed to ensure worker safety. While robots are effective at replacing humans in hazardous tasks, workers responsible for maintaining or repairing these machines may be exposed to new risks. Similarly, the automation of tasks – both cognitive and physical – can significantly improve OSH conditions, but if not properly assessed and managed, can also introduce new hazards. A summary of possible risks associated with automation and advanced robotics, as highlighted by available research, includes the following issues.

Safety risks. Common safety risks associated with workplace robotics include human-robot interaction issues, inadequate safety measures, mechanical and programming failures and human error, all of which can lead to accidents and increased strain on workers (Ken Institute 2024). Workplace accidents can result from unpredictable robot behaviour. Software glitches, sensor failures or AI misinterpretations, may lead to unexpected movements or mechanical failures, causing crushing injuries, fractures or lacerations, particularly in industrial settings (EU-OSHA 2022a). UAVs pose the risk of blunt force trauma or lacerations, especially to operators or service personnel, due to sudden malfunctions or loss of control (Smith 2019; Arterburn et al. 2017; Campolettano et al. 2017).

Exoskeletons with poor fit or design, particularly for female workers, can lead to injuries, mobility restrictions and increased risks of falls (CCOHS 2022a; Flor 2023). In emergency situations, these devices may impede quick evacuation or cause malfunction-related injuries (Akyıldız 2023; IOSH 2023). Additionally, their use in high-temperature environments can elevate the risk of heat-related issues, as exoskeletons retain body heat and robots generate excess heat during charging (Mikołajczyk et al. 2023).

Over-reliance on automation, including robotic systems and exoskeletons, can contribute to deskilling, reducing workers' ability to respond effectively to unexpected situations (Tegtmeier et al. 2022). Furthermore, cybersecurity vulnerabilities in these systems pose functional safety risks, as cyberattacks could override protective mechanisms, potentially leading to hazardous, unintended machine operations (Korfmacher 2019).

Ergonomic risks. Poor posture during human-robot interaction and exoskeleton use can lead to postural strain and musculoskeletal disorders (ILO 2019; Costantino et al. 2021). Collaboration with cobots may lead to ergonomic strain from repetitive tasks, as workers must maintain specific postures or make continuous small adjustments to guide or interact with the machine. Over time, these repetitive movements can contribute to fatigue, muscle strain and chronic pain (Tegtmeier et al. 2022). While exoskeletons are designed to reduce physical strain, they can also exacerbate musculoskeletal disorders if they are too heavy or if they force the body into unnatural or repetitive movements. These risks are heightened when devices are not properly designed or adjusted to the individual worker's body shape, size, and specific task requirements. Moreover, both robotic systems and exoskeletons lack gender-sensitive design, making them less ergonomic for women, who may experience greater strain and reduced usability due to differences in hand size, reach and strength requirements (Hislop et al. 2024).

Noise and vibration risks. Robots and exoskeletons can introduce noise and vibration hazards, potentially contributing to hearing damage and musculoskeletal discomfort if not well-designed (Costantino et al. 2021).

Chemical risks. Batteries in these technologies may overheat or release corrosive materials, posing risks of burns and chemical exposure to workers (Costantino et al. 2021). Additionally, prolonged contact with plastic and metallic components may cause skin irritation or allergic reactions, particularly in workers using wearable exoskeletons or in hot or humid conditions. In certain industries, automation may exacerbate existing chemical hazards. For example, mechanized mining can increase the risk of silicosis due to the generation of more hazardous dust (Hoy et al. 2022).

Organizational and psychosocial risks. The introduction of automation and advanced robotics can introduce new psychosocial risk factors that can impact workers' mental health, job satisfaction and overall well-being. Some key risks relate to the following:

- **Job control.** The use of robotic systems can significantly reduce job control, limiting workers' ability to make decisions or exercise creativity and judgement. This can lead to emotional exhaustion, irritability and decreased job meaningfulness, particularly in sectors such as manufacturing and services (EU-OSHA 2022a; Smids et al. 2020).
- **Work pace and workload.** Automation often intensifies work by imposing tight schedules and increasing task pace, leading to higher stress, error rates and fatigue. Workers servicing or working

alongside robots must adapt to the machine's rhythm, often with limited flexibility and without sufficient recovery time, increasing the risk of physical and mental exhaustion (EU-OSHA 2022b). This need to match robotic efficiency sustains pressure on workers, particularly in fast-paced environments such as manufacturing and logistics, where continuous alignment with robotic systems may lead to fatigue, stress and reduced job satisfaction over time (Smids et al. 2020). Cognitive overload is another concern, as workers must monitor and interact with complex robotic systems while ensuring their tasks align with automated workflows, reducing the balance between routine and advanced tasks and further increasing mental strain (EU-OSHA 2024b).

- **Task design.** Automation can segment work into small, repetitive tasks, reducing workers' sense of accomplishment and autonomy. In some cases, advanced robotics and AI systems create monotonous "microtasks" that negatively affect job satisfaction and morale, while also restricting autonomy and reducing job meaningfulness (Bérastégui 2021; Tegtmeier et al. 2022; Bankins and Formosa 2023). Additionally, the division of work into small, outsourced tasks can lead to fragmented careers, vulnerable employment and diminished job satisfaction (EU-OSHA 2023g).
- **Social isolation.** As workplaces become increasingly automated, human interactions often diminish, as well as peer or managerial support, leaving workers more immersed in technologies and data. This isolation can affect social well-being and create a less engaging work environment (Marsh, E., Vallejos, E. P., & Spence, A. 2022).
- **Inequalities and discrimination.** The implementation of automation and advanced robotics can unintentionally exacerbate workplace inequalities. For instance, the design and application of robotics technologies may overlook the needs of certain groups, such as women or workers with physical differences, leading to ergonomic issues or exclusion from certain tasks (Flor 2023; CCOHS 2022a). Older workers may also face greater challenges in adapting to new technologies, as they may take longer to acquire the skills needed for their effective use, potentially leaving them at a disadvantage compared to younger colleagues (IMF 2024a). Additionally, workers in lower-skilled roles or sectors with limited access to training may face higher risks of job displacement, further widening the gap between high- and low-skill occupations (Murray 2024).
- **Job insecurity and career development.** A major concern regarding automation and digital technologies is their impact on employment and inequality. Workers in lower-skilled roles or those unfamiliar with new technologies may experience heightened stress and anxiety due to job displacement risks, with 21 per cent of European workers (EU-OSHA 2023b) and 22 per cent of US workers expressing concerns about potential job loss, wage reductions and psychological stress (Saad 2023). The uncertainty surrounding automation-driven changes can contribute to long-term mental strain, particularly for workers lacking opportunities for reskilling or career progression. Over time, these fears typically diminish, as job losses are not systematic and vary significantly across sectors and roles (Tamers et al. 2020; Dekker et al. 2017). However, the greatest impact is often on job quality, influencing work intensity, autonomy and skill requirements, rather than on overall employment levels (ILO 2023).

▶ Technostress: an emerging challenge

"Technostress" has emerged as a consequence of continual technological change and, it is likely that it will continue to increase It is a form of stress caused by difficulty adapting to new computer technologies, including the technological demand to work longer and faster, the difficulty in understanding certain tasks or uncertainty surrounding AI systems as they constantly update (Rohwer et al. 2022).

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1.2 Smart OSH tools and monitoring systems

Digital monitoring technologies enable continuous tracking of workplace hazards, allowing for immediate alerts and the timely implementation of preventive and control measures. These systems integrate sensor-based technologies, smart wearable devices, UAVs, AI-driven analytics and conventional wireless technologies[7] to assess ergonomic risks, noise levels, air quality, extreme temperatures and workers' physiological parameters (EU-OSHA 2022g; Sabino et al. 2024; Brous et al. 2020). By monitoring workers' movements, posture, heart rate, body temperature and fatigue levels, these tools generate critical exposure and health data, supporting injury prevention, early detection of health risks and a safer and healthier working environment (Aksüt et al. 2024; Costantino et al. 2021).

Smart digital systems are increasingly used in high-risk sectors such as mining, construction, agriculture, textiles and chemicals, where physically demanding work and hazardous conditions heighten accident risks. These technologies provide continuous monitoring, enhancing worker protection and reducing risks (Aksüt et al. 2024). In addition to offering immediate alerts for potential risks, they can collect valuable data across industries, supporting the adoption of evidence-based preventive measures (O'Brien 2023).

[7] Conventional wireless technologies supporting monitoring systems include Bluetooth, Radio Frequency Identification, Wi-Fi, infrared and camera systems.

Smart safety management system in Seoul (South Korea)

The Seoul Metropolitan Government has launched a Smart Safety Management system to enhance OSH in small and medium-sized construction sites (Seoul Metropolitan Government 2021). This initiative uses AI, Internet of Things (IoT) sensors, and real-time monitoring to detect potential hazards—such as structural risks or worker non-compliance with safety protocols—and to send immediate alerts to supervisors. The system enables early identification of risk factors and facilitates swift interventions to prevent accidents, particularly in high-risk environments. It also integrates data for trend analysis, helping improve long-term safety planning. By leveraging these technologies, the city aims to reduce accidents and improve safety oversight, especially on sites that traditionally receive less regulatory attention.

1.2.1 How smart OSH monitoring is improving safety and health at work

▶ Workplace environmental sensors and AI-driven systems

Environmental sensors track air quality, noise levels, temperature and humidity, helping to identify workplace hazards.[8] They can detect air pollutants, hazardous gases and vapours, triggering alerts to warn workers of unsafe conditions before they become critical (Zamanian 2023). Smart climate control systems adjust heating, ventilation and air conditioning settings to maintain safe working conditions, mitigating risks from excessive heat or cold (ILO 2024).

Drones equipped with cameras, temperature and gas sensors, and GPS are particularly valuable in remote or hazardous environments, such as disaster sites or confined spaces, where human access is limited (Kanellakis and Nikolakopoulos 2017). AI-driven video surveillance enhances safety by monitoring worker movements and behaviours, issuing real-time alerts for unsafe actions such as improper lifting, and detecting hazards such as slips, trips, falls and personal protective equipment (PPE) non-compliance (Katwala 2017; O'Brien 2023). Additionally, AI-powered predictive maintenance systems detect early signs of machinery malfunctions, preventing equipment failures and reducing accident risks (O'Brien 2023).

Reducing accidents using AI-powered OSH video analysis

In 2022, the Turkish Confederation of Employer Associations (TİSK) partnered with a technology start-up to launch the project "Türkiye's Journey to Zero Accidents" using AI-powered OSH video analysis to identify hazards early and prevent accidents (TİSK 2022). Intenseye, deployed in over 25 countries, has captured over 15 million unsafe acts and conditions. The technology aims to improve safety, productivity and work quality. The project supports 200 companies from 21 sectoral organizations. The AI system has been integrated into their facilities, and companies have reported a decrease in workplace accidents.

[8] The Internet of Things (IoT) enhances monitoring capabilities by enabling remote measurement of environmental conditions, such as temperature, sound and humidity, in industrial settings.

Building on these capabilities, AI-based tools integrate data from multiple sources to support proactive OSH management, identifying and mitigating risks before they escalate into accidents. Beyond physical hazards, digital monitoring can track excessive work hours, missed breaks and signs of emotional stress, allowing for timely interventions to prevent overwork and burnout (EU-OSHA 2023h). By analysing patterns of fatigue and stress, AI-driven systems provide personalized recommendations and targeted support, further enhancing worker well-being and overall safety (Vorecol 2024). AI-powered mental health chatbots, for instance, can analyse communication patterns to identify psychosocial risks and offer support (Cameron et al. 2017).

AI-based tool to prevent workplace accidents among temporary workers[9]

In October 2024, a leading recruitment company introduced a cutting-edge AI-powered digital tool within its operations in France, aiming to predict and mitigate workplace accidents, with a particular focus on temporary workers. Temporary workers often face heightened safety risks due to their limited familiarity with job roles and diverse job environments. The new tool uses AI to analyse a wide range of data, including worker profiles, task requirements and past incident patterns. By examining over thirty key factors - such as physical workload, work environment and specific job risks - the system identifies hazards that could lead to accidents. This data-driven approach allows employers to address risks before they escalate. For instance, targeted safety initiatives, such as tailored training sessions, on-site inspections or customized onboarding programmes, can be introduced to better prepare workers for their assignments.

Enhancing driver safety with AI-powered technology[10]

AI-powered fleet camera systems are transforming fleet safety by providing real-time insights into complex road situations and reinforcing safe driving behaviours. Using advanced computer vision and faster “edge computing”, the system captures and analyses video in real time, sending alerts to drivers. They help mitigate risks such as distracted driving, drowsiness and unsafe road conditions. Some systems also include driver coaching tools, using analytics to reinforce safe practices and address risky behaviours. These systems are widely used across industries such as construction, delivery, trucking, logistics and food services, where fleet safety is critical.

[9] https://www.groupe-adecco.fr/adecco/securite-au-travail-et-prevention-des-accidents-du-travail-adecco-developpe-le-premier-outil-predictif-base-sur-lintelligence-artificielle/
[10] https://www.powerfleet.com/ai-video-telematics-for-safe-fleets/

▶ Smart wearable devices

Worn on or near the body, **smart wearable devices monitor workers' health and safety**, providing **real-time risk detection**. These devices track physiological signs such as heart rate, body temperature and stress levels, as well as environmental factors such as air quality and noise levels. They provide immediate alerts on potential risks, enabling timely responses (Tucker et al. 2024).

A specific example of wearable technology is smart personal protective equipment (PPE), which combines traditional PPE, such as protective garments, with sensors, batteries, data transfer modules and other technological elements (EU-OSHA 2020).

Figure 1 illustrates various types of wearable technologies.

▶ Figure 1 - Examples of wearable technologies

Smart helmets	**Wearable cameras**	**Emergency medical information** (Emitags)	**Physical workload and ergonomic sensors**
Actively monitor users' heart rate, body temperature, location and work environment.	Create real-time photos and videos from a first-person perspective, for use in supply chain management and security monitoring, dust monitoring, process control and field inspection.	Intelligent, life-saving devices that can be secured to a hard hat or other flat, clean surface. Contain employees' emergency information, including allergies, health conditions, medications and emergency contact details.	Worn on the hip, back or arm, can alert a user when they perform potentially unsafe movements or tasks (such as improper lifting) and support risk assessment of poor ergonomic work environments.

Smart gloves	**Life band**	**Smart clothing,** e.g. vests	**Smart glasses**
Gloves containing chromogenic material change colour when in contact with hazardous substances.	A flexible strap that can be worn alone or placed inside a user's headwear, it monitors and alerts operators to apparent fatigue and decreased alertness.	Equipped with sensors for detecting environmental hazards and weather changes as well as potential hazards related to reduced visibility, these garments offer real-time vital signs monitoring, heat stress	Offer hands-free safety information, augmented reality for tasks and remote assistance, addressing eye strain concerns and potential distractions.

Source: BIS 2024; GAO 2024; Aksüt, et al. 2024; EU-OSHA 2020; EU-OSHA, n.d.

Wearable technologies help mitigate common workplace hazards, including slips, trips, falls and exposure to harmful substances. Devices equipped with accelerometers detect improper posture and movements, alerting workers to unsafe lifting techniques and ergonomic risks (Zhu, R., Song, R., Wang, Y., Wang, H., and Dong, X. 2021). Wearable air quality sensors monitor volatile organic compounds, carbon monoxide and other toxic gases, providing real-time exposure alerts to protect workers from respiratory hazards (EU-OSHA 2022g; DHS 2023). In high-risk jobs such as firefighting, chemical sensors help monitor air quality and detect hazardous conditions, reducing exposure risks (EU-OSHA 2022g).

Using wearable sensors for early detection and treatment of falls from height at work

One of the main causes of fatalities occurring on construction sites is falls from height. Medical literature emphasizes that the time elapsing after an accident is a critical factor for survival and avoiding permanent disability. A study by Dogan and Akcamete (2019) examined the use of wearable devices to detect accidents caused by falls from height on construction sites and provide a real-time notification to the emergency medical team. Evaluation of the system found that falls were detected correctly, with an alert message sent to the nominated recipients with 100 per cent accuracy.

A smart helmet for improving safety in the mining industry

A smart helmet has been developed which includes various features such as two-way communication, detection of hazardous gases, notification in the case of helmet removal or collision, a panic switch for emergency situations and GPS to track the location of the miner (Dhanalakshmi et al. 2017). Once a poisonous gas is detected, the helmet closes and an oxygen supply is provided by the opening of a valve in the oxygen cylinder. Temperature and pressure sensors are also used for the continuous monitoring of environmental conditions. The information is sent to the control room via a wireless network.

Another example, a wearable dust assessment sensor, has been developed by the US National Institute for Occupational Safety and Health (NIOSH).11 The Helmet-CAM system pairs a lightweight body camera with a dust monitor to evaluate when, where, and how miners are exposed to hazardous dust. Its accompanying software, EVADE (Enhanced Video Analysis of Dust Exposure), synchronizes video footage with logged dust data to pinpoint high-risk tasks and environments. This generates valuable insights and leads to interventions to reduce exposure and improve safety on-site.[11]

11 https://blogs.cdc.gov/niosh-science-blog/2024/11/04/monitoring-rcs-mining/

Wearable real-time motion warning system to prevent musculoskeletal disorders in construction workers

Work-related musculoskeletal disorders, especially in the lower back and neck, are prevalent in construction workers due to prolonged exposure to unsafe postures. Yan et al. (2017) developed a real-time motion warning system using wearable inertial measurement units to help workers monitor and correct risky postures. The system sends alerts via a smartphone app when hazardous movements are detected, helping prevent injuries without distracting workers. Tested in both laboratory and field conditions on a construction site in Hong Kong (China), this system offers an effective, non-intrusive way to reduce musculoskeletal risks on construction sites. However, it should be noted that bad posture can result from fatigue, work pressure and injuries from other tasks, which should be considered in risk assessments.

In noisy or vibration-intensive industries, such as construction and manufacturing, wearable technologies assess noise and vibration levels, ensuring compliance with safety thresholds and issuing alerts when exposure exceeds safe limits. Similarly, wearable sensors track heart rate and body temperature, helping to prevent heat-related illnesses or hypothermia by prompting timely breaks and hydration (Evalan 2025).

Reducing workplace noise exposure with smart hearing protection

Smart hearing protection technology can provide feedback to workers on harmful noise levels and detect noise hazards overlooked by conventional risk assessments. In 2021, a 12-month trial conducted in a high-speed railway construction project in the United Kingdom of Great Britain and Northern Ireland demonstrated how smart ear defenders collect data on at-ear noise exposure, environmental noise levels and personal hearing protection use, enabling real-time monitoring and worksite noise mapping (British Safety Council 2024). These systems not only protect workers from harmful noise but also help adjust working methods and eliminate noise hazards at the source.

Findings revealed previously unrecognized noise risks and cases where prolonged exposure, even with hearing protection, exceeded safe thresholds. Changes made on the basis of the data collected by this technology contributed to a 50 per cent reduction in overall noise exposure, highlighting its effectiveness in improving workplace safety and enhancing traditional noise assessment methods in high-risk sectors such as railway construction.

Following the success of the trial, a new requirement was introduced within the construction site. Contractors with workers exposed to hazardous noise levels (80 dB and above) were required to use active-only hearing protection with integrated monitoring.

Beyond physical health, wearable devices can support mental well-being by monitoring stress, fatigue and emotional state, allowing for early interventions to prevent burnout (Yorita et al. 2023).

Additionally, location-tracking features improve emergency response and worker safety, allowing supervisors to identify workers' locations during evacuations or critical incidents, ensuring a faster response (BIS 2024).

1.2.2 Potential risks associated with smart monitoring systems

While wearable devices and smart monitoring systems offer significant benefits for worker safety, they also introduce potential risks that must be carefully assessed and managed. Importantly, the **hierarchy of controls**[12] should guide the use of smart PPE, which must be considered a last resort. These devices are not a substitute for eliminating hazards at their source and may inadvertently encourage risk tolerance, especially when adverse biological monitoring results are not immediately apparent. Additionally, a focus on acute risks could divert attention from chronic issues, such as long-term health problems, or repetitive injuries that develop over time. While wearable technologies can effectively monitor conditions such as fatigue or heat stress, they do not address underlying factors such as excessive work hours and other psychosocial risk factors.

The main OSH challenges associated with these technologies, as highlighted in the literature, are described below.

Safety risks. Water infiltration into sensor-based wearable devices may lead to short circuits or electric shocks (EU-OSHA 2022g). System malfunctions or data transmission errors can delay alerts and increase the risk of accidents if workers overly rely on automated warnings instead of maintaining situational awareness (EU-OSHA 2023f). Electromagnetic fields generated by these devices could also interfere with medical implants, such as pacemakers (EU-OSHA 2020). While rare, some studies suggest that prolonged exposure to radiation emitted by wearable devices might pose superficial health risks (Costantino et al. 2021).

User comfort and acceptance. The effectiveness of wearable technologies heavily depends on user comfort and acceptance. Devices that are cumbersome, poorly designed or uncomfortable can lead to non-compliance (GAO 2024). Sizing issues, particularly regarding differences in gender and body types, further complicate usability. Prolonged use of these devices may result in physical discomfort, fatigue or feelings of helplessness, especially during technology failures or outages (Patel et al. 2022).

Organizational and psychosocial risks. Wearable devices, such as smart watches, can distract workers, impairing their focus and overall performance. Additionally, surveillance features in these devices may induce stress by creating high-pressure work environments (Star Knowledge 2022). In some cases, by addressing only symptoms rather than root causes, monitoring technologies may inadvertently perpetuate a cycle of stress and overexertion, ultimately affecting workers' overall well-being. The constant monitoring of physiological and biometric data may also lead to anxiety, as workers feel pressured to maintain specific performance or health metrics. This stress can be compounded by complex safety alerts that require frequent interpretation, adding cognitive strain to daily tasks (EU-OSHA 2022g).

Privacy and ethical concerns. Monitoring technologies raise significant privacy and ethical issues through the use of surveillance to track workers' movements and physiological data. While intended to improve safety, the systems can sometimes devolve into constant monitoring, with workers' behaviour reported to managers, potentially leading to automated reprimands or penalties for unmet performance targets. This shift from safety enhancement to worker surveillance can foster distrust and create a high-pressure, stress-inducing work environment (Internet Society 2015). Ethical concerns also arise regarding how collected data is used, stored and shared. Workers may have limited control over their personal health information, raising questions about consent, data security and potential misuse by employers or third parties (EU-OSHA 2024f).

[12] See box on p.46.

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1.3 Extended and virtual reality

Extended reality (XR)[13], and particularly virtual reality (VR), are emerging as effective OSH training tools across sectors. These technologies allow workers to practise tasks in a controlled environment, reducing accident risks during training and improving skill retention.

Beyond training, VR and XR can support hazard identification and workplace safety planning. For example, in manufacturing and construction, they enable virtual prototyping, project testing and three-dimensional model visualization, helping to identify hazards before physical work begins. In the logistics and automotive sectors, real-time instructions and data overlays help reduce errors and physical strain (Williams 2019). In healthcare, immersive simulations allow medical professionals to rehearse complex procedures safely, improving decision-making and precision without endangering patients.

[13] Extended Reality (XR) is an umbrella term for immersive technologies, including Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). VR creates an immersive experience in a visually isolated three-dimensional space, typically experienced through specialized hardware. AR is an experience that integrates virtual elements into the user's physical space. MR blends digital and physical environments, allowing interaction between real and virtual objects.

1.3.1 How extended and virtual reality are improving safety and health at work

▶ Transforming OSH training

VR is transforming training by providing immersive, interactive experiences for high-risk environments that are difficult to simulate theoretically, such as emergency response, fire training and working at heights (EU-OSHA 2024d). This technology allows workers to experience realistic situations and practise safety procedures and emergency responses in a controlled setting. This enhances skill development and decision-making while reducing real-world accidents, injuries and exposure to hazardous materials (O'Brien 2023). It is widely used in sectors such as construction, mining, energy, laboratories and plants to enhance skills and improve safety behaviours, including emergency response procedures (Akyıldız 2023; Srinivasan et al. 2022).

Immersive virtual environments allow workers to acquire new skills quickly and retain knowledge more efficiently, thereby providing a better trained and more competent workforce. The technology presents an important opportunity to improve the effectiveness of safety and safety-relevant training due to its abilities both to allow trainees to fail safely and to present scenarios that are difficult to replicate in the real world, either due to financial constraints or safety concerns (Stefan et al. 2023). Studies have found that 40 per cent of learners using VR reported increased confidence compared to classroom learners, and a 35 per cent improvement in e-learners acting on what they had learned (PWC 2020). Another study in Chile found that workers trained in OSH through VR reported higher satisfaction levels compared to those trained using traditional methods. Workers particularly valued the realism and interactivity, and the engaging, surprising and novel aspects of the VR training format.

VR training for firefighters

Some fire departments in Australia have adopted VR training simulators to prepare firefighters for high-risk scenarios with the support of Australian technology companies. These immersive simulations allow trainees to experience realistic fire conditions that would be too dangerous to replicate in real life.

The VR technology generates highly realistic smoke, fire, water and fire-extinguishing foam, simulating diverse emergency situations such as house fires, aircraft fires and wildfires. Trainees also wear heat suits that mimic real temperatures, with software adjusting the intensity based on their proximity and orientation to the fire, enhancing the realism and effectiveness of the training experience (Hoey 2024).

VR training is also being adopted to train inspectors, equipping them with the skills and knowledge needed to assess workplace risks effectively. By immersing inspectors in realistic, interactive simulations, VR enhances hazard recognition, compliance checks and enforcement strategies while reducing exposure to actual workplace risks (Aati et al. 2020).

VR training for inspectors

VR training for work zone inspections in the United States of America

In Missouri, United States, an interactive VR training platform was developed to train Department of Transportation inspectors responsible for monitoring work zones (Aati et al. 2020). The research team designed two immersive motorway work zone scenarios, allowing inspectors to experience realistic site conditions and practise compliance assessments. Of the 34 inspectors who tested the platform, 97 per cent agreed that VR provided a realistic and effective training tool.

Qatar's VR training programme for labour inspectors

The Qatar Ministry of Labour, in cooperation with the ILO, launched a VR-based training programme for labour inspectors, the first of its kind in the region (State of Qatar 2022). This initiative enhances OSH enforcement by allowing inspectors to explore virtual construction sites, identify workplace risks and correct safety violations without entering hazardous environments. The programme also improves guidance for employers and workers, strengthening compliance with OSH standards.

VR training for ship sanitation inspections

To address the shortage of trained port health officers, worsened by the COVID-19 pandemic, the World Health Organization (WHO) launched a VR training tool for ship sanitation inspections. This interactive platform provides hands-on training, enabling inspectors to conduct comprehensive sanitation assessments, perform risk evaluations and engage with ship crews in a controlled environment. By simulating real-world conditions, VR enhances OSH knowledge and preparedness, ensuring that inspectors can effectively identify and mitigate sanitation risks. The initiative benefits over 230 ports in the WHO European Region and 41 States parties to the International Health Regulations authorized to issue sanitation certificates (WHO 2024).

▶ Enhancing hazard identification

Beyond training, XR is increasingly used by employers for workplace risk assessment and hazard identification. By creating virtual models of work environments, XR enables safety professionals to identify potential risks before physical work begins, particularly in hard-to-reach or hazardous locations such as confined spaces, and high-risk industrial sites (EU-OSHA 2024d). This technology allows for proactive safety planning, reducing the likelihood of accidents and improving overall workplace safety.

VR for OSH hazard detection in Australia

Melbourne Water, a state-owned water authority in Australia, adopted VR technology to improve OSH hazard identification in its facilities (Australian Water Association, 2017). The Melbourne Water VR inspection system allows teams to model future projects and detect safety hazards in wastewater treatment facility designs before construction begins.

In 2017, a pilot at the Cresswell water treatment plant demonstrated the effectiveness of this approach, identifying 20 safety hazards using VR compared to just six hazards detected with traditional methods. Many of these risks were ergonomic issues that might have been overlooked in conventional assessments. Since then, the system has been implemented in the design of over 10 facilities, significantly enhancing pre-construction risk mitigation.

▶ Using XR and VR for safe remote operations

XR and VR technologies can support workers in safely performing remote tasks such as machine maintenance and the operation of hazardous equipment by simulating real work environments and allowing controlled interaction with virtual systems. This reduces the need for physical presence in dangerous settings, helping workers avoid direct exposure to high-risk environments. As a result, XR contributes to accident prevention, enables safer and healthier workflows, and allows for faster emergency response, particularly in sectors such as mining, construction, and heavy industry (EU-OSHA 2024d).

1.3.2 Potential risks associated with extended and virtual reality

The use of XR technologies can introduce several OSH risks that need to be carefully managed. According to the literature, these risks include the following:

- **Blocked visibility.** VR headsets may block visibility, increasing the risk of collisions or tripping over obstacles (Bérastégui 2024).
- **Disorientation, impaired balance and coordination.** VR use can affect balance and coordination, raising the risk of slips, trips, and falls (The United Kingdom of Great Britain and Northern Ireland 2020).
- **Eye health risks.** The use of augmented reality (AR) display screens can, depending on the proximity of the screen to the eyes and the length of exposure, lead to computer vision syndrome, characterized by eye strain, fatigue and sleep deprivation (Bérastégui 2024; Friemert et al. 2019; Stoltz et al. 2017; Marklin et al. 2022). Furthermore, light from AR and VR screens can damage the retina and cause heterophoria (Bérastégui 2024). To prevent these symptoms, it is recommended that sessions last no longer than 55 to 70 minutes (Kourtesis et al. 2019).
- **Cognitive overload.** High volume of data or content may lead to cognitive overload and related damage (Friemert et al. 2019).
- **Acute stress.** AR and VR technologies can trigger acute stress due to technological complexity, digital skill gaps and information overload (EU-OSHA 2024d).
- **Seizures.** High rates of modulation in VR headset light is a risk factor for seizures in individuals with photosensitive epilepsy (Anses 2021).

▶ The use of XR and cybersickness

Cybersickness[14] is a motion sickness-like experience in XR, caused visually by factors such as camera movement, rotation, speed and acceleration (Oh and Son 2022). Symptoms include visual fatigue, headache, pallor, sweating, dry mouth, dizziness, ataxia, nausea and tiredness (Souchet et al. 2023).

Studies show that cybersickness affects between 20 and 80 per cent of VR users, with factors such as age, gender and prior experience with VR influencing susceptibility (Brun 2020). Older adults (over 50 years of age) are more likely to be impacted, as are women (Easa 2021). It has been suggested that the higher incidence of cybersickness in females may be linked to headset ergonomics, with females more likely to experience a poor fit than males (Stanney et al. 2020). This may mean that female workers may be more at risk than males when using VR in the workplace.

[14] https://www.frontiersin.org/research-topics/12692/cybersickness-in-virtual-reality-versus-augmented-reality

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1.4 Algorithmic management of work

Algorithmic management (AM) allocates, monitors and evaluates work tasks and workers' performance through extensive data collection, surveillance, real-time decision-making and metrics-driven evaluations (Mateescu and Nguyen 2019). AM integrates digital technologies such as big data analytics, machine learning, geolocation and wearable devices to automate or support functions traditionally performed by human managers (ILO 2022). While its use is particularly prevalent on digital labour platforms, AM has expanded to traditional sectors, including warehouses, factories, call centres, transportation, healthcare and construction (ILO/European Commission 2024). For instance, in the United States of America, 80 per cent of the largest private employers track individual worker productivity using AM systems (Kantor et al. 2022).

1.4.1 How algorithm management is improving safety and health at work

AM systems have the potential to promote worker engagement and satisfaction by focusing on support rather than control. For instance, approaches such as gamification can enhance job satisfaction by creating a more engaging work environment (Hughes et al. 2019). Additionally, aligning tasks with employees' preferences and fostering collaboration among colleagues can lead to a more fulfilling workplace. Studies have shown that when workers are involved in the task allocation process and their preferences are considered, they report increased satisfaction and performance (Feng & Farris 2020). AM systems can also support managers by streamlining decision-making, improving access to information, and reducing repetitive tasks and stress (Milanez, Lemmens, and Ruggiu 2025).

AM systems can improve work-life balance by optimizing scheduling practices. Algorithms can ensure that workers are not overburdened, providing adequate time off while maintaining operational efficiency (ILO 2021e). These systems can also help distribute tasks more equitably among workers on the basis of the data collected, reducing perceptions of favouritism or unfair workloads, which are common sources of workplace stress (Mateescu and Nguyen 2019).

AM can promote skill development. AM systems can identify skill gaps and recommend personalized training plans, helping workers adapt to technological changes. This proactive approach not only mitigates anxiety related to job security but also enhances confidence, empowerment and long-term career growth (Murray 2024).

AM systems have the potential to address workplace violence and harassment, such as cyberbullying, by analysing communication patterns and detecting inappropriate behaviours (EU-OSHA 2022d). For example, Sánchez-Medina et al. (2020) described an AI-based tool capable of identifying links between certain personality traits (such as psychopathy) and cyberbullying behaviours. However, the use of such behavioural software requires ethical oversight to prevent misuse or unintended consequences.

1.4.2 Potential risks associated with algorithmic management of work

The implementation of AM can create OSH challenges that require careful assessment and mitigation.

Safety risks. Functional safety risks may arise due to cybersecurity threats. Data breaches or hacking incidents could compromise automated safety controls, leading to unexpected malfunctions or exposing workers to hazardous environments due to faulty AI-driven decision-making (EU-OSHA 2022h).

Ergonomic risks. The sedentary nature of algorithmically managed tasks, especially in desk-based roles, increases the risk of musculoskeletal disorders, including back and neck pain (EU-OSHA 2023d). Prolonged sitting combined with strict algorithm-driven schedules that limit movement can lead to poor posture, muscle stiffness and chronic pain conditions (EU-OSHA 2023d).

Organizational and psychosocial risks. The use of AM systems can introduce new stressors, which may impact mental health, job satisfaction and overall well-being. Some key risks include the following.

- **Job control and autonomy.** AM systems often supervise, monitor and control work processes, reducing workers' autonomy. For example, constant tracking of activities - such as keystrokes, call durations and break times - can leave workers with little decision-making power (Piasna 2024; CDT 2021). This level of surveillance, paired with metrics-based performance evaluations, can lead to exhaustion, stress and physical health issues such as back pain, headaches and cardiovascular problems (Bérastégui 2021).

- **Workload and work pace.** Data-driven AM systems can increase workload and time pressure by setting productivity targets or providing real-time recommendations, often encouraging workers to work faster and longer without adequate breaks (EU-OSHA 2023f, Moore 2018). Algorithm-driven penalties, such as automatic deductions for minor delays or mistakes, further heighten anxiety and pressure, impacting workers' mental health (EU-OSHA 2023f). To increase productivity, organizations might implement systems that direct workers to work without mini-breaks, minimize the time for certain procedures or force them to work at high speed (EU-OSHA 2022d). Gamification strategies may incentivize excessive work intensity, while algorithms sometimes penalize workers for taking extended breaks (ILO 2021e). This constant pressure can lead to stress, dissatisfaction and physical symptoms.
- **Task design and career development.** If AM systems are not designed with fairness in mind, they can perpetuate harmful biases in hiring, promotions and task allocation, disadvantaging certain groups based on race, gender or other factors (Murray 2024; Jarrahi et al. 2023). Such practices can harm worker morale and negatively impact company culture. Additionally, AI-driven performance evaluations may contribute to job insecurity, as workers fear automation-driven assessments could replace human judgement, affecting promotions and job stability (EU-OSHA 2024b).
- **Social isolation.** Extensive use of AM may prioritize productivity over peer interaction, leaving workers feeling lonely and disconnected. Reduced peer and managerial support and communication can contribute to social isolation and dissatisfaction (EU-OSHA 2022d; Bérastégui 2021).

The impact of algorithmic management on job quality and working conditions in selected countries

A 2024 ILO/European Commission report studied the impact of AM practices on work organization, job quality and industrial relations in logistics and healthcare sectors in France, Italy, India and South Africa. It found that AM technologies had a positive impact on work organization in France and Italy, with no significant negative effects on job quality or increased worker surveillance. In contrast, in South Africa and India, AM led to a decline in job quality, with clear evidence of increased monitoring, surveillance and work intensity. These differences highlight the role of institutional and regulatory frameworks in shaping AM's impact, emphasizing that it is the implementation, not the technology itself, that influences outcomes (ILO/European Commission 2024).

- **Privacy and ethical concerns.** The digital tools used for surveillance purposes in AM systems are particularly intrusive and have the capacity to collect a constant flow of data and information about a worker's location, actions and behaviour, even during non-work hours. Techniques to monitor work rates and attendance, for example, include automatic facial recognition, communications scanning and analysis, location tracking and the recording of remote workers' keystrokes through webcams, screen activity or voice recording (Ball 2021). These surveillance techniques can impact employee well-being, work culture, productivity, creativity and motivation (Ball 2010). Aside from the constant monitoring, workers may also be bombarded with alerts, warning and reminders, which are stressful as they give the sense of constant oversight (EU-OSHA 2022g).

1.5 Changing work arrangements through digitalization

The digitalization of workplaces has transformed traditional office-based work into remote, telework and hybrid arrangements, while also expanding online and platform work.

The COVID-19 pandemic accelerated this transition, with public health measures prompting widespread adoption of telework across many sectors (ILO/WHO 2021). Advances in teleworking and digital collaboration technologies have further enabled this shift, allowing workers to communicate, manage tasks and perform job functions remotely with greater efficiency (Elsamani and Kajikawa 2024).

While the prevalence of full-time telework has declined post-pandemic, hybrid work routines have become the norm. For instance, a US study found that 41 per cent of workers with jobs that can be done remotely are now working on a hybrid schedule (Parker 2023). However, not all jobs can be done by telework. In the EU, 38.5 per cent of dependent employment is estimated to be compatible with remote work, it being more common in higher-paid, computer-intensive jobs requiring advanced education (Eurofound 2022). Telework is most prevalent among highly skilled workers, particularly women, urban residents, and those in service sectors such as finance, information technology and journalism (Eurofound 2022; WEF 2023). Examples of roles highly suited to telework include database professionals, financial analysts and office clerks (Eurofound 2022).

Beyond telework, digitalization has also facilitated the expansion of digital labour platforms, reshaping traditional employment structures. Digital labour platforms now play a major role in the evolving work landscape, organizing and intermediating services through both online and location-based tasks. Online platforms support a range of work activities such as translation, design, data analytics, content moderation, software development, writing, virtual assistance and customer support. Location-based platforms use a device's location to manage on-demand services such as ride-hailing, food delivery, home care, cleaning, pet sitting, repairs, event planning, personal shopping and courier services. Globally, an estimated 154 million to 435 million[15] workers engage in online platform work, representing up to 12 per cent of the global labour force (Datta et al. 2023). The number of online platforms has grown significantly, with estimates increasing from 193 in 2010 to 1,070 in 2023, with developing countries seeing a particularly rapid growth in demand. These platforms foster innovation and create opportunities for workers, businesses and society. Among them, 357 focus on online work, followed by delivery services (334), individual passenger transport (119), care work (121), domestic work (117), and hybrid platforms (22) offering multiple services (ILO 2024c).

1.5.1 How new work arrangements are improving safety and health at work

One of the key advantages of remote work is the flexibility can offer. Online work arrangements allow workers to better adjust their schedulles and work tasks to better suit their individual needs. Digital technologies facilitate working anytime and anywhere, eliminating the need for a fixed workplace and reducing commuting time, so workers can dedicate more time to personal development and family life (ILO/Eurofound 2017; McAllister et al. 2022; EU-OSHA 2023d). This flexibility not only reduces stress and supports mental health but also fosters skill development, creativity and a better balance between professional, family and social responsibilities (ILO, 2021). For instance, in France, 85 per cent of teleworkers surveyed reported greater freedom to manage their time, while 88 per cent noted improved work-life balance on telework days (Lasfargue and Fauconnier 2015). This autonomy often leads to higher job satisfaction and better personal well-being (Indradewa 2023).

Digital platforms can favour inclusion by creating opportunities for marginalized workers, including people with disabilities, older adults and those with care responsibilities. By breaking down geographical and institutional barriers, platform work provides employment to individuals who might otherwise face challenges accessing traditional job markets, such as women managing caregiving duties or workers in underserved areas (ILO 2021a; ILO/Eurofound 2017).

For older adults and individuals with disabilities, platform work offers remote options that eliminate the need for commuting or navigating inaccessible workplaces (ILO 2021d). For example, remote work and online platform work can significantly increase employment opportunities for individuals with mobility limitations (EU-OSHA 2023e).

[15] Estimation depending on the method used.

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1.5.2 Potential risks associated with remote work and online work

Remote work poses challenges for employers in ensuring a safe and healthy working environment. Without direct oversight or regular risk assessments, hazards such as poor ergonomics, environmental risks and inadequate safety measures can go unnoticed, amplifying OSH concerns (ILO/WHO 2021). Platform work presents additional risks, as many workers operate in less regulated environments with limited protections (ILO 2019; Eurofound 2022). This challenge is further compounded by the growing number of self-employed workers, who often fall outside existing OSH regulations, raising concerns about accountability for workplace safety and health. Evolving business models and employment structures driven by online and flexible work, along with the rise of algorithmic management and AI, are transforming work organization, making it increasingly difficult to uphold safety standards and ensure adequate OSH protections (EU-OSHA 2025).

Environmental and safety risks. Without regular risk assessments, remote workspaces may have inadequate lighting, poor air quality, electrical hazards and thermal discomfort. Additionally, home-based workers can face fire hazards and poor emergency preparedness, as safety regulations are not systematically enforced in private residences (EU-OSHA 2024c). Platform workers, particularly those in delivery and ride-hailing services, encounter heightened safety risks, including a higher likelihood of road accidents due to long working hours, tight deadlines and hazardous traffic conditions (EU-OSHA 2024e; ILO 2024c). Furthermore, independent contractors often lack employer-provided safety measures, leaving them without proper training, protective equipment or access to occupational health services, increasing their vulnerability to work-related injuries (Eurofound 2022).

Ergonomic risks: Many remote workers lack proper workstation setups, increasing the risk of musculoskeletal disorders such as lower back and neck pain (Fadel et al. 2023). In Mexico and India, only 27 per cent and 16 per cent of homeworkers respectively have a dedicated workspace (ILO 2021d). Common ergonomic risks include prolonged sitting, repetitive hand and wrist movements and poor screen positioning, which can contribute to physical discomfort, eye strain and fatigue (EU-OSHA 2021a). The sedentary nature of desk-based platform work further exacerbates these risks, contributing to obesity, diabetes, and cardiovascular diseases, as workers spend extended hours without adequate movement breaks (EU-OSHA 2024b). Additionally, working in non-optimized environments, such as cafés or shared spaces, can increase physical strain due to inadequate seating, inappropriate desk heights and excessive background noise, affecting both comfort and productivity.

Eye health risks. The American Optometric Association[16] warns that individuals who spend two or more continuous hours on screens are at particular risk of eye strain. Additionally, blue light exposure from high-intensity screens can disrupt sleep patterns and potentially harm retinal cells (Cougnard-Gregoire et al. 2023).

Organizational and psychosocial risks. Working remotely for a long time has been linked to employee burnout, emotional exhaustion, psychological strain, reduced job performance, high turnover and low levels of professional accomplishment (Costin et al. 2023).

- **Increased workload and work pace.** Teleworkers can experience high levels of demand and intensity at work due to close monitoring, extended working hours and expectations of constant availability (ILO/Eurofound 2017). Studies acknowledge that teleworkers typically work longer hours than their office-based counterparts (Rebelo et al. 2024). In a survey of 406 teleworkers workers in France, 61 per cent stated that their working time had increased (Lasfargue and Fauconnier 2015). Furthermore, some teleworkers continue working despite illness, avoiding taking sick leave - "presenteeism" - potentially leading to long-term burnout (Steidelmüller et al. 2020; EU-OSHA 2024c). For platform workers, workload intensification is often driven by algorithmic scheduling, with AI setting performance targets that encourage continuous engagement and limit opportunities for rest (EU-OSHA 2023h).

[16] https://www.aoa.org/aoa/documents/healthy%20eyes/digital_eyestrain.pdf

- **Loss of job control and autonomy.** The amplified use of digital surveillance practices to monitor remote workers may have wide repercussions for job quality, leading to work intensification, reduced work autonomy and reciprocal mistrust between workers and management (EU-OSHA 2023h). Samek Lodovici et al. (2021) studied the implications of remote working on flexibility, autonomy, work intensity, work–life balance and health and safety, finding that constant surveillance and algorithm-driven decision-making may create anticipatory stress, reducing worker well-being and increasing mental strain.
- **Social isolation and poor work-life balance.** Virtual communication channels often result in reduced social interaction, leading to feelings of isolation, loneliness and weaker peer relationships, which can compromise productivity and creativity (Figueiredo et al. 2024; Shirmohammadi et al. 2022). For example, 56.8 per cent of home-based remote workers in the European Union (EU) reported social isolation (EU-OSHA 2023e). Similarly, 63 per cent of Brazilian teleworkers cited isolation from colleagues as a key drawback of their work arrangements ((ILO/Eurofound 2017). Online work may also require unsocial hours, limiting workers' flexibility in managing their schedules and impacting work-life balance, potentially exacerbating social isolation (ILO 2021e). Platform workers, especially those engaged in on-demand services such as ride-hailing and food delivery, often lack a stable work community, further contributing to social disconnection (Eurofound 2023).
- **Violence and harassment:** While remote workers or teleworkers, due to their isolation, are generally less exposed to physical violence or direct harassment from peers and third parties, remote and online work environments can also exacerbate workplace bullying, as harmful behaviours such as derogatory language, social exclusion and threats may be more persistent in digital spaces (Javed et al. 2023). Cyberbullying can lead to severe stress, anxiety and long-term mental health impacts (Farley et al. 2015). Workers in customer service roles are particularly vulnerable to online abuse from customers, while journalists and public-facing professionals face increased digital harassment (PersVeilig 2021). Platform workers, particularly those in delivery and ride-hailing services, also face significant risks of both online and physical violence. Many report experiencing verbal abuse, threats and physical attacks from customers or other road users, with some incidents escalating into robbery or assault (EU-OSHA 2023h; ILO 2024c). The lack of employer-provided security measures, such as emergency support systems or clear violence prevention policies, further exacerbates these risks. A survey of 165 social partner organizations found that 80 per cent of respondents viewed third-party violence and harassment as a serious issue, with verbal and psychological harassment being the most reported forms (Pillenger 2023). For platform workers, the absence of designated safe workspaces and the unpredictable nature of their interactions increase their vulnerability to both harassment and physical violence (Eurofound 2023).

▶ Guidance on Healthy and Safe Telework

The ILO and the WHO developed the technical brief entitled *Healthy and Safe Telework* (ILO/WHO 2021). The brief aims to provide technical information to employers, teleworkers and worker representatives about the impact of telework on health, safety and well-being. It provides practical advice on organizing and carrying out telework in a way that protects and promotes physical and mental health and social well-being.

The digitalization supply chain: *OSH considerations*

Although millions of workers are, and will continue to be, impacted by digital technologies, special consideration should be given to those who directly contribute to the industry, particularly in production, waste management and technology application. This matter is explored in Feeding the Machine. The Hidden Human Labour Powering AI (Muldoon et al. 2024), which examines the invisible workforce fuelling the growth of AI. Regardless of the job sector or role, digital technologies such as AI, are often powered by millions of lower paid workers, performing repetitive tasks under challenging labour conditions (Williams 2022). Some of these jobs have existed for years, but the rapid expansion of specific sectors has increased pressure on workers, often without adequate OSH protections. Additionally, many of these workers are part of the informal economy and are therefore not covered by OSH laws or regulations.

Workers powering digital technologies

Data annotators

Data annotation – the process of preparing data for computer learning models – presents significant OSH challenges. It can take several forms, including labelling, tagging, transcribing and processing. The work is seen as unskilled, yet high-quality and accurate annotation is expensive and time-consuming (Smart et al. 2024). Workers often perform highly repetitive tasks under strict surveillance, facing exploitative and unregulated labour practices (Rani and Dhir 2024; Williams 2022). Many are required to classify toxic content without adequate transparency, fair compensation or resources to address the psychological impact of exposure to disturbing material (Jensen 2024).

Content moderators

Content moderators play a critical role in ensuring online spaces remain safe by analysing and removing offensive or harmful user-generated content. They are expected to process 500 to 1,000 tickets daily, exposing them to graphic (Muldoon et al. 2024) and explicit material without adequate mental health support or time to recover from what they witness. This continuous exposure to violent and disturbing content poses serious mental health risks, including symptoms of post-traumatic and secondary traumatic stress, compassion fatigue, and burnout (Rani et al., forthcoming). Despite these risks, some moderators are required to sign disclaimers, acknowledging the potential for adverse mental health effects and post-traumatic stress disorder from their work (BBC News 2021).

Machine learning engineers

A machine learning engineer is a technically proficient programmer who builds AI systems that utilise huge data sets to generate and develop algorithms capable of learning and making predictions (BrainStation 2024). Their work is associated with attractive salaries, cutting edge technologies, variety and high demand (run:ai n.d.). However, the job can be demanding and stressful due to the complexity and overwhelming volume of data involved (teal n.d.).

Big data analysts

Big data refers to large and complex datasets produced by sources such as people, machines or sensors, which grow rapidly in size (European Commission 2016) and are too large for traditional data management systems to handle (Google Cloud n.d.). Big data analytics involves examining these datasets using tools such as AI, machine learning and statistical analysis to extract meaningful insights (Ishwarappa and Anuradha 2015). However, challenges related to data privacy, security and governance persist, particularly when dealing with sensitive information (Rawat and Yadav 2021). Additionally, a shortage of skilled professionals in data science and analytics limits the potential of big data environments (Google Cloud n.d.).

Workers in technology production and waste management

Miners excavating critical minerals

Critical minerals such as cobalt, lithium and copper are essential components of digital technologies, but their extraction, often in informal mines, puts workers in dangerous conditions (Wilson Center 2021). The rapid growth of demand for these minerals due to technological advancements places additional pressure on the mining sector, and workers, particularly in developing countries, face significant safety risks and limited OSH protections (Landrigan et al. 2022). For example, more than half of the world's cobalt supply, used in portable electronic devices and rechargeable batteries, comes from the Democratic Republic of Congo, where extraction of the mineral is linked to informal operations where there are child labour, safety risks, environmental abuses and corruption (Wilson Center 2021).

Factory workers in technology assembly

Technology assembly line workers face long hours and unsafe working conditions, with minimal compensation (Judge 2023). However, the integration of AI and automation could improve production processes and safety standards by reducing human error and workload in hazardous environments.

Electronic waste

As the production and use of technology rapidly expands, the amount of electronic waste (e-waste) is expected to increase to 75 million tonnes by 2030 and reach 111 million tonnes by 2050 (Parajuly et al. 2019). E-waste is becoming an increasingly important resource for informal workers along the e-waste value chain who recover, repair, refurbish, re-use, repurpose and recycle electrical and electronic equipment, however workers are often exposed to hazardous working conditions (ILO 2021c). This is posing serious health risks (cancer, lung diseases and cardiovascular diseases) due to toxic chemicals and improper disposal (ILO 2021c).

However, AI and automated systems could improve the recycling process, reducing exposure to harmful substances and ensuring more efficient resource recovery.

Environmental and occupational health considerations

Digitalization has emerged as a key player in reducing pollution and fostering a shift towards a low-carbon economy (Huang et al. 2024). AI-powered systems such as smart meters, active power grids and sensors can enhance energy efficiency and reliability, contributing to safer and more sustainable work environments while helping to reduce the impacts of climate change (OECD n.d.). As demonstrated in several recent ILO publications[17][18], climate change presents a variety of OSH risks to workers, particularly through exposure to excessive heat, solar ultraviolet radiation, air pollution, extreme weather events, vector-borne diseases and chemicals.

In workplace technologies, AI combined with VR and AR, **facilitates remote working and virtual collaboration**, reducing the need for travel and lowering workplace carbon footprints. For instance, transitioning from in-person to virtual meetings can cut carbon emissions by 94 per cent and energy use by 90 per cent (Tao et al. 2021). These advancements not only improve sustainability but also enhance worker safety by minimizing exposure to hazardous environments.

However, AI's growing energy demands and environmental costs must be considered. AI-driven data centres, significantly more energy-intensive than typical cloud applications, are projected to increase global carbon emissions and water consumption, underscoring the need for sustainable practices in their operation (Goldman Sachs 2024).

Focusing on integrating AI into OSH responsibly can maximize its benefits while minimizing its environmental impact, supporting safer, healthier and more sustainable workplaces.

17 See Ensuring safety and health at work in a changing climate (ILO, 2024)
18 See Heat at Work: Implications for safety and health (ILO, 2024)

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2

Addressing OSH in the Digital Era: Policies, Gaps, and Collaborative Efforts

As workplaces rapidly adopt new technologies, there is a growing focus on using their potential benefits while mitigating the significant risks they pose to worker safety and health.

New initiatives at international, regional and national level increasingly address the intersection of OSH and digitalization. These efforts include incorporating provisions related to new technology into OSH policies and practices while embedding OSH considerations into broader digitalization strategies.

While existing OSH regulations generally safeguard workers by addressing all types of risks, including those resulting from digital technologies, targeted legislation to mitigate the specific impacts of digitalization is quite limited. Alongside legislative updates to address these gaps, voluntary standards, training programmes and awareness campaigns are vital to fostering safer work environments. Research and data collection on the positive and negative impact of digitalization on workers' safety and health are essential for informed policymaking. Social partners play a crucial role in shaping these responses to the integration of digital technologies into the workplace. Their involvement is essential for ensuring that these technologies are designed and implemented in ways that are safe, healthy and equitable (Berg et al. 2023).

This section examines global, regional and national efforts to safeguard OSH in the digital transition, along with workplace-level action to harness the benefits of digitalization while preventing and managing emerging risks.

2.1 Global efforts to ensure safe and healthy work in the digital transition

2.1.1 The role of the ILO

Ensuring the fundamental principle and right of a safe and healthy working environment requires addressing the challenges of evolving workplaces, where new and emerging hazards - including those introduced by digitalization - must be managed alongside persistent risks. This involves embracing the benefits of digitalization while understanding and mitigating its potential risks.

The fundamental OSH Conventions (namely, the Occupational Safety and Health Convention, 1981 (No. 155) and the Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187)[19] provide a comprehensive framework for a systems-based approach to OSH, which remains adaptable to evolving workplace risks.

[19] Member States, regardless of ratification status, are required to respect, promote and realize the provisions set out in the Fundamental OSH Conventions

▶ The relevance of the OSH fundamental Conventions to addressing the new challenges associated with digitalization

Convention No. 155 lays down fundamental objectives and defines the basic principles of a coherent national OSH policy. It covers workers in all branches of activity and is the most comprehensive of the current standards. Convention No. 187 advocates for the continuous improvement of national OSH frameworks, ensuring that policies remain responsive to changes in the world of work, including those driven by digital transformation.

- Member States, in consultation with the most representative employers' and workers' organizations, should **formulate, implement and periodically review a coherent national policy on OSH and the working environment**, the aim being the prevention of occupational accidents and injuries by eliminating or minimizing the causes of hazards, according to Convention No. 155 (Article 4). In the context of digitalization and an ever-evolving world of work, OSH policies can integrate challenges and opportunities associated with emerging technologies, outlining measures to assess and mitigate their risks.
- Article 4(3) of Convention No. 187 highlights the **role of tripartite bodies in promoting a preventive safety and health culture**, ensuring that all relevant stakeholders - governments, employers and workers - are actively involved. Tripartite bodies can play an important role when confronting new technologies that are being rapidly deployed in workplaces, ensuring that proper preventive measures are put in place.
- Workers have the **right to remove themselves from situations they reasonably believe pose imminent and serious danger** to life or health (Article 13, Convention No. 155). This right extends to situations posed by new technologies, for example malfunctioning advanced robots.
- Employers, so far as is reasonably practical, **must ensure that machinery, equipment, and processes under their control are safe and do not pose health risks** (Article 16, Convention No. 155). This obligation extends to digital tools and automated systems, where employers should address potential risks associated with new technologies, such as those arising from human-machine interactions, system malfunctions, and ergonomic or mental health concerns tied to digitalization.
- Convention No. 155 underscores the importance of **providing adequate training and information to workers** – a principle that becomes even more critical as new digital technologies, such as AI or XR, are introduced (Article 19).
- Articles 19 and 20 of Convention No. 155 emphasize the importance of **cooperation between employers and workers on implementing OSH measures at the workplace level**.

Conventions Nos. 155 and 187 highlight the critical role of employers' and workers' organizations in the management of OSH, at both the national and workplace level. This collaboration ensures that OSH policies are inclusive and address challenges posed by digitalization, balancing technological advancements with the protection of workers' safety and health.

In addition to the fundamental conventions, other OSH instruments provide valuable provisions and information that are relevant to improving the OSH aspects of digitalization.

- The **Occupational Health Services Convention, 1985 (No. 161)** emphasizes the role of occupational health services in identifying and assessing workplace risks and providing guidance on organizing work, including workplace design and the use of machinery, tools and equipment.
- The **List of Occupational Diseases Recommendation, 2002 (No. 194)** includes diseases caused by physical, chemical and biological agents, musculoskeletal disorders and mental and behavioural disorders, which may be relevant to the increase in digitalization.
- The **Violence and Harassment Convention, 2019 (No. 190)** establishes a framework for preventing and mitigating violence and harassment in the world of work, including incidences occurring through digital technologies, which can be relevant for preventing cyberbullying and other risks associated with increased digitalization.

In addition to the existing Conventions and Recommendations, a standard-setting item on decent work in the platform economy will be discussed during the 113th (2025) and 114th (2026) sessions of the International Labour Conference, which will include OSH considerations.[20] Future normative action is also planned for ergonomics and machine safety.[21]

Among the ILO's various technical guidelines and codes of practice, the **Code of Practice on Protection of Workers' Personal Data**[22] offers guidance that is particularly relevant in a world of work increasingly characterized by the processing of large amounts of worker data.

The ILO is actively addressing the challenges and opportunities of digitalization for work through a range of initiatives aimed at supporting governments, workers and employers in navigating this transformation. For instance, the ILO Global Strategy on Occupational Safety and Health 2024-2030[23] emphasizes the need for research and tools to navigate the opportunities and challenges of new technologies. The ILO also launched the Observatory on Artificial Intelligence and Work in the Digital Economy[24] which aims to serve as a knowledge hub to support governments and social partners in understanding and managing the digital transformation of work[25].

Furthermore, the ILO's recent publication, Social Dialogue Report 2024: Peak-level Social Dialogue for Economic Development and Social Progress, highlights the critical role of social dialogue in addressing workplace transformations driven by digitalization, emphasizing collaboration among governments, employers, and workers to ensure equitable outcomes and decent work in the digital era.

Several research initiatives at the sub-regional level are actively exploring the intersection of OSH and workplace digitalization. These include:

- Research on digital labour platforms in Uganda, Nigeria, India and Kenya.
- Case studies on AM practices are being undertaken, covering sectors such as retail and banking in Chile, automobile manufacturing in Argentina and Malaysia and electronics in Malaysia. Case studies were also conducted on AM practices in logistics and healthcare in Italy, France, India and South Africa (ILO/European Commission 2024).
- Surveys on AI supply chains are being conducted in business process outsourcing companies in India and Kenya, with plans to include the Philippines eventually.

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20 See GB.347/INS/2/1/Decision
21 See GB.331/LILS/2
22 https://www.ilo.org/resource/other/protection-workers-personal-data
23 https://www.ilo.org/sites/default/files/wcmsp5/groups/public/%40ed_protect/%40protrav/%40safework/documents/policy/wcms_897539.pdf
24 https://www.ilo.org/all-resources-for-topic?cf0=1781%206106%206126
25 It currently covers four thematic areas: AI, AM, digital labour platforms and workers' personal data, although there are plans to expand to more subject areas in the future.

2.1.2 International initiatives

International groups have created broad initiatives to address the challenges brought about by digital technologies.

- The **G7 Action Plan for a Human-centred Adoption of Safe, Secure and Trustworthy AI in the world of work** emphasizes the enforcement of labour laws and OSH standards, while monitoring AI's impact on OSH, including risk assessments and audits.

International OSH institutions are also developing activities and initiatives that focus on specific aspects of digitalization and its impact on safety and health at work.

- **The International Ergonomics & Human Factors Association**[26] has organized several webinars related to AI and human-robot interaction. In these webinars, international experts on robotic research present perspectives on human factors and ergonomics in robotics.
- The **Institution of Occupational Safety and Health**[27] has actively engaged in initiatives addressing digitalization in OSH. This included organizing a webinar series on "Demystifying AI for Health and Safety", which brought together experts to explore how AI can be used to enhance safety protocols, improve risk management and streamline workplace operations.
- The **International Organization for Standardization has several standards related to information technology and artificial intelligence, including risk management**[28]. Safety standards have been developed for the industrial robotics sector[29] as well as for the non-industrial (service) robotics sector[30]. Other topics for robot standardization activities include performance criteria, modularity and vocabulary (IFR n.d.). There are currently no technical or safety standards focused exclusively on exoskeletons. However, an existing international standard, "Robots and robotic devices - Safety requirements for personal care robots"[31] addresses safety requirements for personal care robots, some of which may be considered as exoskeletons.

International employers' and workers' organizations are increasingly undertaking initiatives to address the opportunities and challenges presented by digitalization in the workplace.

- The **International Organisation of Employers (IOE)** has been advocating for skills development and training to ensure that the workforce is well-equipped to handle digital transformations, recognizing the importance of incorporating OSH considerations into the implementation of new technologies. As part of this effort, the IOE has published several reports, including Mental Health and Wellbeing at Work, which examines mental health in the broader context of workplace digitalization and the integration of new technologies (IOE 2023). In addition, a policy review by the IOE delves into the impact of AI on work and employment, emphasizing its transformative potential for business, while offering strategic guidance on the effective adoption and management of AI technologies by employers (IOE 2024). Moreover, the IOE and Deloitte published a significant *G20 2024 Readiness Report: AI Powered Transformation*",[32] which highlights that while AI has the potential to enhance productivity and efficiency greatly, it also presents challenges that must be proactively addressed, such as job displacement and the risk of exacerbating social disparities.
- **Global trade unions** have also been proactive in addressing the implications of digitalization for workers. The **International Trade Union Confederation** advocates for stronger regulation of AI and digital surveillance to protect workers from discrimination and work intensification[33]. It also pushes for OSH protections and collective bargaining rights for platform workers impacted by digitalization. **UNI Global Union's report**, *Algorithmic Management - A Trade Union Guide*,[34] examines the growing use of algorithmic management tools in workplaces worldwide, providing guidance for trade unions on how to approach negotiations over their development and application. Furthermore, the first **International Trade Union Forum on the Impact of Digitalization on the Financial System**,[35] held in Fortaleza, Brazil in June 2022,

[26] International Ergonomics & Human Factors Association
[27] AI and tech in safety and health
[28] Including ISO/IEC 42001:2023 and ISO/IEC 23894:2023
[29] Including ISO 10218-1, ISO 10218-2, ISO/TS 15066
[30] ISO 13482
[31] ISO 13482:2014
[32] G20 2024 Readiness Report: AI Powered Transformation
[33] AI IS NOT OK | Union action needed on Artificial Intelligence (AI) at work
[34] Algorithmic management - A trade union guide
[35] International Trade Union Forum seeks solutions to the impacts of digitalization on the financial system

brought together over 600 union leaders from 24 countries to discuss solutions for mitigating the effects of digitalization and automation in the financial sector. **IndustriALL Global Union** has also established an Industry 4.0[36] expert group to develop a policy paper on digitalization, AI and Industry 4.0[37] focusing on worker participation, the protection of rights and ensuring a just transition to digitalization for workers. **Building and Wood Workers' International** conducted a study on the national and international impacts of digitalization on construction workers, shedding light on the industry's specific challenges[38].

2.2 Regional initiatives to harness OSH through digitalization

Various regional initiatives have been launched worldwide, encompassing actions related to digitalization in general, as well as targeted schemes related to a particular technology. However, outside Europe, these initiatives tend to focus more on broader issues, such as the ethical use of AI, rather than on OSH.

In **the EU**, several regulatory frameworks govern OSH in the context of digitalization, AI and advanced robotics:

- OSH Framework Directive 89/391/EEC[39] – Remains fundamental as it establishes general principles for worker safety and health, including risk prevention, worker consultation and training. While not specifically designed for AI-based systems and robotics, its broad scope allows it to address associated risks.
- Machinery Regulation (EU) 2023/1230[40] – Replacing the Machinery Directive 2006/42/EC, this new regulation (effective 2027) strengthens binding health and safety requirements for advanced machinery, robotics, and AI-driven systems. It directly addresses concerns about the 2006 directive's ability to manage AI-related risks.

36 Also known as the Fourth Industrial Revolution (4IR).
37 Protecting workers' rights in Southeast Asia amid transformation
38 https://www.bwint.org/web/content/cms.media/1837/datas/EN_FoW_Study_Oct2019.pdf
39 Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work
40 Regulation (EU) 2023/1230 of the European Parliament and of the Council of 14 June 2023 on machinery and repealing Directive 2006/42/EC of the European Parliament and of the Council and Council Directive 73/361/EEC (Text with EEA relevance)

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- Artificial Intelligence Regulation (EU) 2024/1689[41] – This new legislation establishes harmonized rules for AI systems, particularly for those classified as high-risk , to ensure transparency, human oversight and appropriate safeguards to minimize risks to health, safety and fundamental rights.
- Directive on Platform Workers (EU) 2024/2831[42] – Aims to improve the working conditions for platform workers, and regulates the use of workplace algorithms. It mandates human oversight in key decisions, including dismissals.

Beyond legislation, initiatives in the EU proactively address the impact of digitalization on OSH.

▶ EU-OSHA's Safe and Healthy Work in the Digital Age campaign (2023-2025)

The Healthy Workplaces campaign[43] raises awareness about the impact of new digital technologies on work and workplaces and the associated OSH challenges and opportunities. The initiative also provides a platform for the exchange of good practice solutions.

The aim of the campaign is to stimulate collaboration for a safe and productive digital transformation of work. One way to make the journey is through strategic planning based on the following five main objectives:

1. Raise awareness about the importance, relevance and implications for OSH of the digital transformation of work, including the business case by providing facts and figures.
2. Increase everyone's awareness and practical knowledge across all sectors, types of workplaces and specific groups of workers (for example women and migrants) about the safe and productive use of digital technologies at work.
3. Improve knowledge about new and emerging risks and opportunities related to the digital transformation of work.
4. Promote risk assessment and the healthy and safe proactive management of the digital transformation of work by providing access to relevant resources (for example good practice checklists, tools and guidance).
5. Bringing stakeholders together to facilitate the exchange of information, knowledge and good practice and stimulate collaboration for a safe and productive digital transformation of work.

Five priority areas give structure to the campaign:

- Digital platform work
- Advanced robotics and AI
- Remote and hybrid work
- Smart digital systems
- Worker management through AI

41 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024R1689
42 https://eur-lex.europa.eu/eli/dir/2024/2831/oj/eng
43 The campaign is mainly based on the findings and resources of the OSH Overview on Digitalisation 2020-2023, a four-year research programme on digitalization of the workplace and its implications for OSH. The campaigns' website (www.healthy-workplaces.eu) offers a wide range of materials and resources designed to help you promote and support the campaigns. Most of these resources are available in 25 languages.

While not exclusively focused on OSH, there are other regional initiatives that are highly relevant as they address working conditions, job security, and workers' rights in the digital era.

- The **African Union** promotes digital and AI-driven development through the Digital Transformation Strategy for Africa 2020-2030[44], part of the broader Agenda 2063, which emphasizes data protection, cybersecurity and workforce digital skills, and the Continental AI Strategy[45], which advocates for development-focused and ethical AI use.
- Within the **Southern Common Market (Mercosur)**, the Presidential Declaration on Digital Integration (*Declaração presidencial sobre a integração digital*)[46] by the governments of Argentina, Brazil, Paraguay and Uruguay underscores the importance of a cohesive regional digital transformation strategy, emphasizing research, development and ethical innovation.
- The **Arab Labor Organization** discussed the future of work in light of AI[47], including a focus on youth empowerment and workplace innovation. While there was no specific reference to OSH, there was a general mention of supporting human capabilities using AI.
- The **Association of Southeast Asian Nations (ASEAN)** regional economic strategy increasingly focuses on the Fourth Industrial Revolution (4IR), which includes the adoption of advanced digital and automation technologies.[48] As part of this strategy, ASEAN launched the ASEAN Digital Integration Framework Action Plan to guide member States in adopting digital technologies across sectors.

Social partners have also implemented a range of different initiatives related to digitalization and OSH.

A notable example of social dialogue is the European Social Partners Framework Agreement on Digitalisation (2020), adopted by European cross-sectoral social partners (BusinessEurope, SMEunited – Crafts & SMEs in Europe, the European Centres of Employers and Enterprises providing Public Services, and the European Trade Union Confederation). This agreement aims to ensure a human-centred approach to digital transformation, addressing its impact on work organization, skills development and OSH. It includes commitments to anticipate and manage workplace changes, promote workers' rights to training and consultation and ensure that digital technologies enhance, rather than undermine, OSH protections.

Regional employers' organizations have produced reports and held discussions to promote the responsible use of technologies in workplaces.

- The **ASEAN Confederation of Employers** is actively involved in promoting responsible AI in the workplace. They have highlighted the need for governance and ethical guidelines in the development and use of AI technologies. Through discussions and awareness-building, they aim to ensure that businesses integrate AI in ways that protect workers' rights and safety. This includes providing resources and insights on managing risks associated with AI implementation, such as job displacement, data biases and privacy concerns.
- **BusinessEurope** has highlighted the importance of skills development and training in response to the growing influence of automation and AI. They have advocated for frameworks that support businesses in adapting to digitalization, including addressing mental health risks linked to remote work and automation. One notable publication is their report, Algorithmic Management at Work: Improving Transparency to Achieve More Trust in AI[49], which explores ways to foster trust in AI-driven systems. At the sectoral level, the **Council of European Employers of the Metal, Engineering and Technology-based industries (CEEMET)** released a report in 2021 titled *Digitalisation and the World of Occupational Safety and Health*[50], which includes sections on cobots, flexible work, sensors and smart PPE as well as ergonomics and exoskeletons

[44] Digital Transformation Strategy for Africa 2020-2030
[45] Continental Artificial Intelligence Strategy
[46] Declaração presidencial sobre a integração digital no MERCOSUL
[47] The Future of Work in Light of Artificial Intelligence
[48] Consolidated Strategy on the Fourth Industrial Revolution for ASEAN
[49] Algorithmic management at work: Improving transparency to achieve more trust in AI
[50] Digitalisation and the World of Occupational Safety and Health

Trade unions have also developed initiatives at the regional level, including reports, policy guidance tools, awareness-raising campaigns and training initiatives.

- The **Trade Union Confederation of the Americas** produced the report *Del Taller al Cronómetro. Del Cronómetro al Algoritmo* which suggests that smart regulations, active trade union action, social dialogue and government commitment are essential components for achieving an AM system that promotes greater sovereignty over working hours, better rights and working conditions for workers.[51]
- The **Caribbean Congress of Labour** has been engaged in discussions about the effects of digitalization in the region.[52] Their efforts focus on ensuring that workers in the Caribbean are not left vulnerable to job displacement caused by new technologies. They promote educational initiatives to improve digital literacy among workers.
- **Public Services International** launched the Our Digital Future project[53] to train union representatives in their **Africa** and **Middle East and North Africa region** on digital rights, AI and OSH in digital workplaces. The initiative equips leaders with knowledge on digital technologies and data rights, enabling them to promote safe, tech-literate work practices within their unions. Workshops and resources are available in Arabic, French and English to ensure accessibility.
- The **European Trade Union Confederation** published the *Resolution on European AI and Data Strategies* (ETUC 2020), advocating for stronger worker participation in AI governance and decision-making. The resolution emphasizes worker protection[54], calling for AI applications affecting workers to be classified as high-risk and subject to strict regulation, ensuring compliance with the precautionary principle.
- The **European Trade Union Institute** published the report *Regulating Algorithmic Management*[55], providing an assessment of the European Commission's draft Directive on improving working conditions in platform work. It states that fair and transparent AM should be guaranteed by strengthening workers' ability to exercise their rights of access to their data fully, rectification, erasure, restriction of processing and data portability. The European Trade Union Institute's Education and the Foresight unit have developed a series of trainings and training tools to introduce AI to workers' representatives.[56]
- The **Council of Nordic Trade Unions** report, *The Future of Work – Technology for People*[57], emphasizes that new technology must ensure individual control over personal data, prioritizing ethical principles, data security and "privacy by design."

2.3 National frameworks governing OSH and digitalization

2.3.1 National policies and strategies

Some countries are incorporating provisions related to the risks of digital technologies into their national OSH policies and strategies, acknowledging the need to protect workers and businesses from these evolving challenges and defining actions to be implemented in the coming years.

- In Argentina, the Superintendence of Occupational Risks adopted the Prevention 4.0[58] strategy, which makes use of digital records for workplace inspections, safety training and equipment provision. This initiative aims to enhance worker protection through digital solutions and strengthen risk management in technologically evolving work environments.

51 Del taller al cronómetro. Del cronómetro al algoritmo
52 The future of digital transformation and workforce development in Latin America and the Caribbean
53 Digitalisation Training - Africa/MENA
54 In this context, the resolution focuses on preventing disproportionate and undue surveillance at work, prohibiting discriminatory treatments based on biased algorithms and preventing abuse of data protection and privacy.
55 Regulating algorithmic management
56 Empowering workers: ETUI's training tools on AI's impact in the workplace
57 The future of work – Technology for people
58 New Prevention 4.0 rules, Superintendence of Occupational Risks (SRT)

- Finland's Policy for the Work Environment and Wellbeing at Work until 2030[59] explicitly mentions the acceleration of technological advancements, including robotics, information and communication technology, digitalization, AI and automation. It stresses the need to identify, prevent and minimize the risks introduced by these technologies, evaluating their potential impact on workers' health as part of the ongoing transformation of work.
- Guyana's National Policy on Occupational Safety and Health[60] (2018) advocates for the use of appropriate technology, modern equipment, current technology and modernized systems while taking into account the varying impacts these may have on the environment.
- India's National Policy on Safety, Health and Environment at the Workplace[61] recognizes the new safety hazards and health risks associated with the adoption of modern technologies. It advocates for the use of safe and clean technologies, as well as the implementation of computer-aided risk assessment tools to better manage risks.
- Uruguay's National Policy on Occupational Safety and Health focuses on updating the OSH regulatory framework to reflect advancements in knowledge, new technologies and changes in the world of work.[62]

Many countries are adopting national strategies on digitalization and AI. While OSH issues are rarely addressed directly, these strategies increasingly promote a worker-centred approach to digital transition. Upskilling, reskilling and education programmes are a key focus, ensuring workers acquire digital skills to adapt to AI-driven job transformation (for example, Egypt[63], Germany[64], Mexico[65], Saudi Arabia[66],Tunisia[67] and Uruguay[68]). Several policies emphasize ethical AI principles, prioritizing human well-being, equity, non-discrimination and data privacy in the workplace (Ireland[69], Mexico[70] and Uruguay[71]). Others address work-related impacts, such as gender equality, inclusion and legal protections for workers, with commitments to review labour laws to safeguard rights (Chile[72]). By prioritizing these areas, national AI strategies reflect a growing global commitment to responsible AI adoption, which will also contribute to safer and healthier working environments.

2.3.2 Regulatory framework addressing the potential risks arising from new technologies

Existing OSH legislation usually provides broad protection to workers against all occupational risks, including those arising from the new technologies and processes discussed in this report. Common provisions in legislation emphasize an employer's duty of care and the requirement for comprehensive workplace risk assessments, which generally encompass concerns related to digitalization. However, OSH laws often prioritize physical hazards – such as those posed by robots and automated processes – and may be less adequate to address the psychosocial risks introduced by digitalization and AI-driven systems.

To address this gap, new regulations are emerging to regulate the design, implementation and use of new digital technologies, to ensure that they enhance workplace safety and health while minimizing associated risks.

- Argentina's Resolution 69/2024,[73] issued by the Superintendence of Occupational Risks, aims to modernize workplace risk prevention through digital technology. It empowers the department to set guidelines for implementing technology-driven safety measures and encourages organizations to adopt digital tools to enhance OSH.

59 Safe and healthy working conditions and Work Ability for everyone : Policy for the Work Environment and Wellbeing at Work until 2030
60 Guyana's National Policy on Occupational Safety and Health
61 National Policy on Safety, Health and Environment at the workplace
62 Uruguay´s National OSH Policy
63 National Artificial Intelligence Strategy
64 Artificial Intelligence Strategy of the German Federal Government
65 Mexico's National AI strategy
66 National Strategy for Data and Artificial Intelligence
67 Tunisia AI Roadmap
68 Uruguay´s National Strategy on AI 2024-2030
69 Roadmap for AI in Ireland
70 Mexico's National AI strategy
71 Uruguay´s National Strategy on AI 2024-2030
72 Chile's National Policy on AI and Chile's Action Plan on AI
73 Resolución 69/2024

Binding regulations on advanced robotics and their impact on worker safety and health remain in their early stages or are absent in many countries.

- France has been actively engaged in regulatory efforts to balance innovation with worker protections. The Digital Labour Code[74] has incorporated specific rules for robot-assisted work environments, focusing on safety, health and ethical concerns. These rules address the safe interaction of humans and robots, ensuring that human-robot collaboration is handled in a way that minimizes risks to workers.
- In Germany, the German Social Accident Insurance (DGUV) standards, such as Regulation 100-500[75], cover industrial machinery and robotics, setting mandatory requirements for employers to ensure the safety of their workers. These regulations cover everything from risk assessments to ensuring proper safety measures are in place for the operation of robots, especially in environments where humans work alongside automated systems.

Some countries are introducing laws to establish the right to disconnect, allowing workers to disengage from work-related communications outside of working hours. These measures aim to prevent burnout, promote work-life balance and reduce excessive digital surveillance. By regulating the use of tools such as email and messaging apps, these laws help safeguard workers' personal time and mental health in an increasingly connected world.

- Luxembourg introduced the "right to disconnect" law in 2023[76], which provides that companies in which employees use digital tools for professional purposes must define a system to ensure that the right to disconnect is respected outside working hours.
- Other countries, including Argentina[77], Australia[78], Austria[79], Belgium[80], Brazil[81], Chile[82], Denmark[83], Germany[84], Greece[85], Ireland[86], Italy[87], Luxembourg, Mexico[88], the Kingdom of the Netherlands[89], Portugal[90], Spain[91], Sweden[92], Türkiye[93] and Ukraine[94] have also enacted similar legislation. In some cases, these laws only apply to enterprises with a certain number of employees, such as in France[95] (50 or more employees) or in Quebec[96], Canada (25 or more employees).

Concerning privacy, national OSH laws generally do not address the significant data security challenges posed by digital technologies and AI in workplaces. While worker data privacy is typically governed by general data protection laws rather than worker-specific regulations, **some countries have introduced specific provisions to protect workers' privacy and data security in an increasingly automated and data-driven working environment.** For instance, France's Labour Code[97] sets out rules on workplace monitoring, such as surveillance cameras and online activity tracking, while Germany's Federal Data Protection Act[98] imposes strict regulations on employee data collection, processing and storage. Australia has also proposed new data protection regulations under its Digital Economy Strategy[99], covering remote work surveillance, biometric data and algorithmic decision-making.

74 https://code.travail.gouv.fr/
75 https://publikationen.dguv.de/widgets/pdf/download/article/997
76 https://www.paulhastings.com/insights/practice-area-articles/luxembourg
77 https://iuslaboris.com/insights/the-right-to-disconnect-which-countries-have-legislated/
78 https://www.fairwork.gov.au/employment-conditions/hours-of-work-breaks-and-rosters/right-to-disconnect#:~:text=An%20employee%20has%20a%20right,the%20Right%20to%20disconnect%20section.
79 https://iuslaboris.com/insights/the-right-to-disconnect-which-countries-have-legislated/
80 ibid
81 https://www.paulhastings.com/insights/practice-area-articles/brazil
82 Ibid
83 Ibid
84 Ibid
85 Ibid
86 Ibid
87 Ibid
88 Ibid
89 Ibid
90 Ibid
91 https://healthy-workplaces.osha.europa.eu/en/media-centre/news/spains-latest-initiative-puts-spotlight-right-disconnect-and-associated-preventive-measures
92 https://iuslaboris.com/insights/the-right-to-disconnect-which-countries-have-legislated/
93 Ibid
94 Ibid
95 https://www.klgates.com/What-is-new-in-France-right-for-the-employees-to-disconnect-02-22-2017
96 https://www.assnat.qc.ca/Media/Process.aspx?MediaId=ANQ.Vigie.Bll.DocumentGenerique_136423en&process=Default&token=ZyMoxNwUn8ikQ+TRKYwPCjWrKwg+vIv9rjij7p3xLGTZDmLVSmJLoqe/vG7/YWzz
97 Légifrance – Code du travail
98 Federal Data Protection Act
99 Digital Economy Strategy

Countries are starting to regulate algorithmic management in workplaces to address risks such as unfair penalties, excessive surveillance and discrimination - gaps not typically covered by general OSH laws.

- China[100] and the Kingdom of the Netherlands[101] have introduced regulations emphasizing fairness and transparency in workplace algorithms.
- In Spain, Law 12/2021[102] amends the Workers' Statute Act, requiring employers to disclose algorithmic parameters affecting working conditions. To support compliance, the Spanish Ministry of Labour and Social Economy issued a guide promoting transparency and fair algorithmic decision-making in digital work environments.
- In the United States of America, the Algorithmic Accountability Act of 2019[103] mandates assessments of high-risk AI and machine learning systems handling personal data or making automated decisions.

Industrial Safetytech Regulatory Sandbox

The rapid evolution of technology presents both opportunities and challenges in industrial safety. While technologies such as AI, the Internet of Things (IoT) and robotics can significantly enhance workplace safety, their adoption is hindered by regulatory uncertainties, sometimes weak business cases and the need for safe development environments. Safetytech Accelerator (STA), a London-based technology accelerator focused on innovation for safety-critical industries, in partnership with the UK Health and Safety Executive's Discovering Safety programme, launched the world's first Industrial Safetytech Regulatory Sandbox in 2023 to address these challenges.

The project aimed to explore effective assessment and compliance activities, accelerate the adoption of proven safety technologies and understand and reduce barriers to the development of new life-saving technologies. The innovative sandbox approach combined HSE's regulatory expertise with STA's innovation programme knowledge. Priority challenges were first identified through consultations, focusing on falls from height, vehicle collisions, crane operations and manual handling. Six innovative tech firms were then selected to undertake investigative studies. They were supported by the Health and Safety Executive and industry mentors to address challenges collaboratively, ensuring solutions were not developed in silos. The sandbox operated over three months and resulted in a set of recommendations to enhance technology adoption in the construction sector. The project successfully demonstrated the potential of collaborative regulatory sandboxes to accelerate the adoption of innovative safety technologies in the construction industry, ultimately contributing to safer and healthier workplaces.

Source: Safetytech Accelerator

The increasing prevalence of telework and digital platform work has prompted many countries to introduce specific legislation to address the unique challenges posed by these evolving work arrangements.[104] For instance, since the beginning of the COVID-19 pandemic, specific legislative initiatives on telework have been passed in many countries such as Austria, Greece, Latvia, Portugal, Romania, Slovakia and Spain (Eurofound 2022). Countries are increasingly introducing laws to regulate

[100] Regulation on Administration of Internet Information Service Recommendation Algorithms (2022)
[101] AI & Algorithmic risks report Netherlands
[102] BOE-A-2021-15767 Ley 12/2021, de 28 de septiembre, por la que se modifica el texto refundido de la Ley del Estatuto de los Trabajadores, aprobado por el Real Decreto Legislativo 2/2015, de 23 de octubre, para garantizar los derechos laborales de las personas dedicadas al reparto en el ámbito de plataformas digitales.
[103] The Algorithmic Accountability Act of 2019 (H.R.2231)
[104] A common concern is that many platforms characterize their businesses as technological intermediaries and consider platform workers to be self-employed. This creates ambiguity regarding the responsibility for implementing essential risk prevention measures, such as risk assessments, OSH training and the provision of protective equipment. In many cases, these obligations are either unclear under existing laws or shifted onto workers, who typically lack the resources to fulfil them (ILO 2024c).

digital platform work, with approaches varying widely. Some legislation focuses on ensuring the correct classification of workers, thereby extending existing employee protections to platform workers. Others aim to provide specific protections, including OSH measures, to all platform workers regardless of their classification, while assigning varying degrees of responsibility to platforms. In some cases, responsibility is explicitly placed on platforms, whereas in others it is shifted to workers.

Collective bargaining agreements complement national legislation, providing additional protections at the sectoral or enterprise level. Some agreements focus on specific technologies such as exoskeletons, AI or algorithmic management, while others take a broader approach.

- In Norway, a collective agreement between the Confederation of Norwegian Enterprise and the Norwegian Confederation of Trade Unions addresses the use of AI in the workplace. It states that companies must keep employees informed through shop stewards on plans and decisions regarding control measures, which can be based on technological, financial, safety and health considerations. Control measures that are introduced must not go beyond the necessary scope and must be factually justified in the individual company's operations and needs. Employee privacy and dignity are paramount, requiring sound AI methods, involvement of employee representatives and prevention of bias (Brunnerová et al. 2024).
- In Spain, the 2023-2024 collective agreement at Tekniker ensures employees' right to disconnect, guaranteeing rest and privacy, and prohibiting work-related communications outside working hours unless exceptional circumstances arise (Brunnerová et al. 2024).
- In Sweden, a new AI surveillance system was implemented in Kiruna Mine, which uses a smartphone application to give workers positioning support, navigation assistance and the ability to receive alerts and emergency information with receipt confirmation (IKAB 2022). However, it was negotiated that it could only be used for safety and not to track or measure productivity.

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Other agreements focus on industry-specific issues.

- In Italy, trade unions representing workers in the commerce, tourism, and service sectors[105] reached an agreement with Partesa, a subsidiary of the brewing multinational Heineken Group, to regulate the use of a telematics app for monitoring delivery drivers. The agreement limits monitoring to safety and productivity purposes, requiring union or work council approval before implementation (Brunnerová et al. 2024).
- In the United Kingdom of Great Britain and Northern Ireland, the GMB union reached an agreement with Hermes addressing certain algorithm-based processes the company uses to manage its fleet of delivery drivers. The agreement grants unions the authority to conduct health and safety assessments following incidents, allowing them to identify cases where AM raises safety concerns (Collins and Atkinson 2023).
- Germany saw the first digitalization agreement in the retail sector, negotiated by UNI Global Union's ver.di and H&M. The breakthrough deal means that workers will have a greater say in how new technology is deployed at the fashion giant, while also offering job security and bonuses (UNI Global Union 2022).

Labour inspectorates play a key role in ensuring compliance with OSH regulations, including in the context of digitalization. Beyond enforcing laws, inspectors provide essential guidance and support to both employers and workers, helping them navigate and implement necessary safety measures in increasingly digital workplaces. Through inspections, training and dialogue, they work to ensure that technological advancements do not compromise worker safety and health.

In addition, labour inspections are increasingly using technologies and AI to improve their priorities and target-setting through algorithms that help identify signs of fraud or non-compliance.

- Mexico's Secretariat of Labour and Social Welfare is deploying an innovative system that uses hazard projection models to optimize workplace inspections (STPS, 2024). The new tool will analyse 1.5 million past inspections to identify areas with a higher probability of non-compliance, enhancing the precision of future inspections. As a result, inspections supported by AI are showing a success rate of 94 per cent (Moncada, 2024). Furthermore, the tool can detect patterns related to occupational diseases and risks, offering valuable insights for preventive actions (STPS, 2024). This information will be shared with the Mexican Institute of Social Security to help the labour authority identify enterprises and workplaces with higher rates of industrial accidents, recurring occupational disabilities or complaints (Gascón, 2025).
- The Norwegian Labour Inspection Authority has developed a predictive analytics tool that utilizes big data to identify high-risk companies for health and safety inspections.[106] This tool analyses various data sources to target inspections more effectively, enhancing the precision of their intervention.

2.3.3 Voluntary standards and technical guidelines

To complement regulatory frameworks, many countries have introduced voluntary standards, technical guidelines and good practices to ensure OSH in the context of digital transformation. While these initiatives are not legally binding, they provide valuable recommendations to support the safe, healthy and responsible adoption of new technologies in the workplace.

Some guidelines focus on promoting the use of digital technologies to improve OSH, enhancing risk management.

- In Argentina, the Libro Blanco: Digitalización para la Prevención de Riesgos en el Trabajo[107], published by the Ministry of Labour, Employment and Social Security, outlines strategies for using digital technologies to enhance workplace risk prevention. It explores digitalization, AI and data analysis as tools for modernizing OSH practices and improving worker protection. It emphasizes collaborative approaches and sets out recommendations for integrating digital tools into risk assessment and management systems.

105 Namely, Filcams CGIL (Federazione Italiana Lavoratori Commercio Albergo Mensa e Servizi) and Fisascat CISL (Federazione Italiana Sindacati Addetti Servizi Commerciali Affini e Turismo).

106 https://osha.europa.eu/en/publications/future-role-big-data-and-machine-learning-health-and-safety-inspection-efficiency

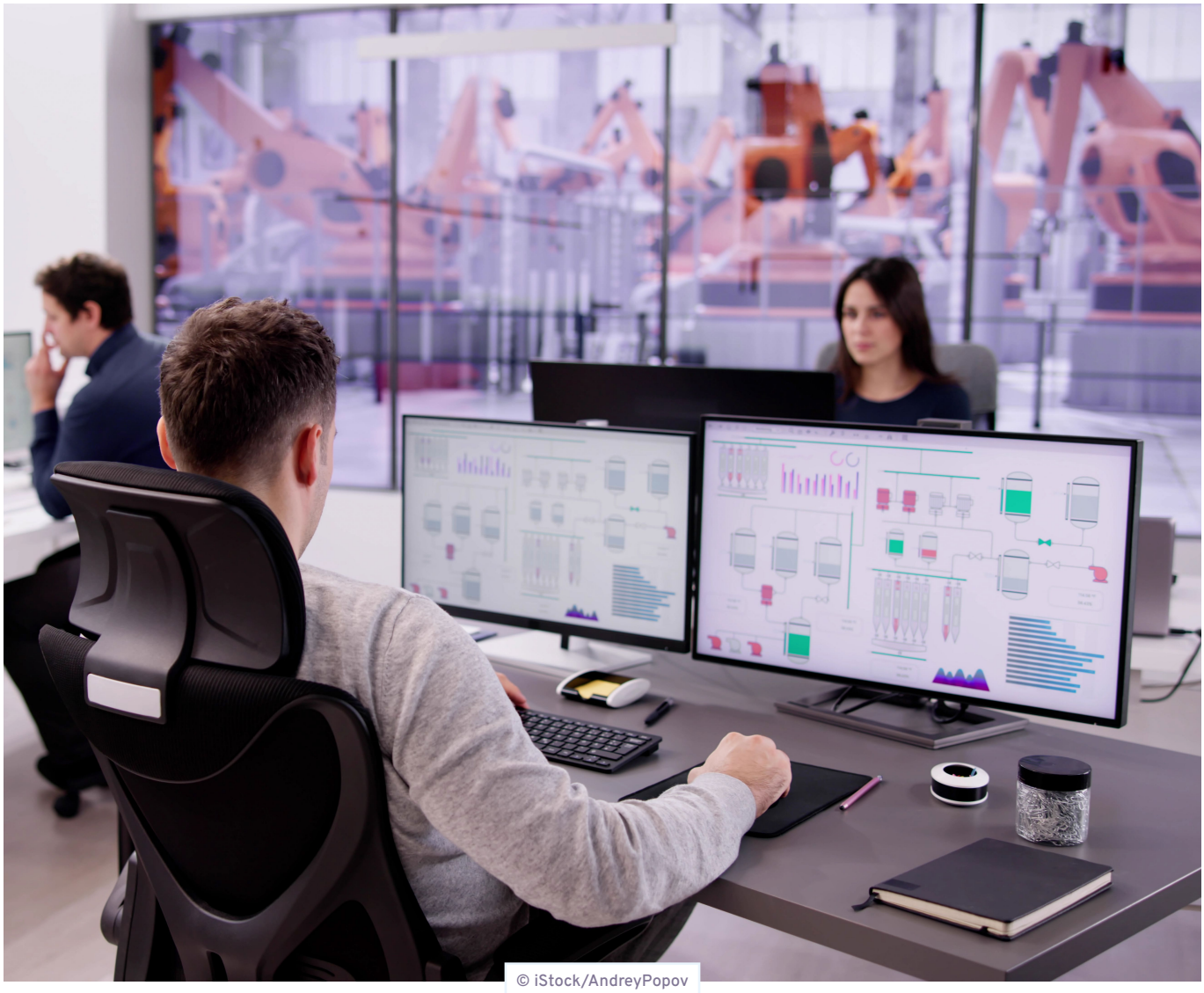
107 Libro Blanco: Digitalización para la Prevención de Riesgos en el Trabajo

- In Canada (British Columbia), WorkSafeBC promotes the use of digital tools for workplace safety and health management. Initiatives include the Employer Health & Safety Planning Tool Kit[108], which enables employers to track injury and claims data, analyse safety performance and identify trends that can inform future health and safety planning. It allows employers to compare their safety performance with industry standards, forecast potential risks and integrate health and safety data into financial planning.
- In France, the National Research and Safety Institute for the Prevention of Occupational Accidents and Diseases publication Intelligence Artificielle au Service de la Santé et Sécurité au Travail: Enjeux et Perspectives à l'Horizon 2035[109] explores how AI could transform workplace risk prevention and improve working conditions by 2035. Key focus areas include AI applications for accident analysis, epidemiology and advanced robotics.

Other guidelines focus on addressing OSH risks and challenges associated with digitalization, particularly with automation and robotics. In some cases, these guidelines adopt a sector-specific or risk-specific approach.

- In Australia, the Guidelines for Safe Collaborative Robot Design and Implementation[110] from the Centre for Work Health and Safety of the New South Wales Government, include key information on OSH considerations for the use of collaborative robots, including safe interaction, design, workplace checklists and risk assessments.
- In the United States, the American National Standards Institute and the Robotics Industry Association introduced the first safety standard for industrial robots in 1986 (the American National Standard for Industrial Robots and Robot Systems – Safety requirements, which has been continuously updated to address new risks, including collaborative robotics. Additionally, the Occupational Safety and Health Administration and NIOSH, in collaboration with the Association for Advancing Automation, have revised parts of the Occupational Safety and Health Administration Technical Manual[111] to cover safety measures for collaborative and mobile robotic systems.
- In France, Prevention in the field of collaborative robotics[112] provides information on the safe implementation of collaborative robots, including risk prevention.
- The Public Health Institute of Chile published guidance on work digitalization and automation[113] which examines how new technologies influence OSH and productivity, offering insights on managing risks associated with increased digital integration in various industries. The guide emphasizes the importance of responsible implementation to support both workforce well-being and efficiency, addressing areas such as ergonomic risks, data handling and automated task safety.
- In New Zealand, WorkSafe has published Guidelines on Automation and Robotics[114] to support enterprises in managing the risks associated with the use of automation, including robotics, encouraging the adoption of proactive measures such as safety audits, training and worker involvement in the implementation process. Sector-specific guidelines have also been published in New Zealand. For example, the Construction Health and Safety Guidelines[115] include recommendations on managing automated machinery, while the Telecommunications Information Privacy Code[116] provides considerations for automation and digital technologies in telecom operations.
- In Ireland, the Psychosocial Risk Assessment: Guidance for Exposure to Sensitive Content[117] was jointly developed by the Health and Safety Authority and the State Claims agency to assist organizations employing people in roles which expose them to sensitive content as part of their assigned duties, such as content moderators, or other employees who are unexpectedly exposed in their role. It provides detailed information about risk assessment, using the hierarchy of controls.

108 Employer Health & Safety Planning Tool Kit
109 Intelligence artificielle au service de la santé et sécurité au travail
110 Guidelines for Safe Collaborative Robot Design and Implementation
111 Industrial Robot Systems and Industrial Robot System Safety
112 Prevention in the field of collaborative robots
113 Digitalización y Automatización en el Trabajo
114 Guidelines on Automation and Robotics
115 Safe use of machinery
116 Telecommunication Information Privacy Code 2020
117 The Psychosocial Risk Assessment: Guidance for Exposure to Sensitive Content



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Some guidelines focus on the implications of AI ethics for workplace safety, particularly in AM and responsible deployment.

- Australia's AI Ethics Principles[118] and New Zealand's AI Ethics Principles[119] promote safe and responsible AI use, encouraging businesses to consider OSH risks, worker safety and privacy concerns.
- Dubai's AI Ethics Principles and Guidelines[120] in the United Arab Emirates and Singapore's Model AI Governance Framework[121] emphasize transparency, accountability and fairness in AI applications.

Employers' organizations are also actively involved in encouraging responsible integration of digital technologies, providing guidance to their members.

- In the United States of America, the Robotic Industries Association[122] issued safety requirements[123] for industrial mobile robots, which describe the basic hazards associated with these robots in an industrial environment and provide requirements to eliminate or adequately reduce the risks associated with them.
- In Japan, the Robotics Safety and Worker Training Programme by the Japan Iron and Steel Federation has issued requirements that operators of robot services or robot service providers should observe.[124] They stipulate rules for risk assessment, safety management, education, operation systems, management systems and other actions that robot service providers should conduct to secure the safety of service robots in providing services for ordinary people in public spaces.

118 The Australian AI Ethics Principles
119 NZ's Artificial Intelligence Ethics Framework
120 Dubai Ethical AI Toolkit
121 Singapore's Model AI Governance Framework
122 A trade group founded in 1974 to serve the robotics industry in North America
123 Industrial Mobile Robots - Safety Requirements
124 New JIS as Safety Standards for Robot Services Established

2.3.4 Awareness-raising initiatives

Awareness-raising initiatives play a critical role in spreading information and encouraging safe and healthy practices to ensure that new technologies contribute to safer and healthier workplaces. These initiatives can be organized by public authorities, OSH bodies or employers' and workers' organizations, taking various forms such as campaigns, workshops, conferences, webinars, podcasts and networks, as well as promotional materials such as reports and factsheets.

Public authorities and OSH bodies worldwide have developed awareness-raising initiatives focusing on the OSH implications of digital technologies.

- Various EU Member States are conducting awareness-raising campaigns as part of the EU-OSHA Healthy Workplaces Campaign 2023-2025, which addresses safe and healthy work in the digital age (see page 31).
- The Canadian Centre for Occupational Health and Safety publishes factsheets such as Introducing New Technology at the Workplace [125], outlining potential hazards and risk management measures for digital technologies. Other factsheets focus on specific technologies, such as robots and cobots[126], and exoskeletons[127], offering detailed guidance on risk management.
- In Finland, the "AI Ethics Challenge"[128] initiative is a challenge for companies, in which they can discuss the ethical rules for using AI.
- In India, the Ministry of Labour and Employment, in collaboration with industry bodies, raises awareness about AI and automation risks, particularly for industries undergoing digital transformation.[129]
- In Mexico, the Secretariat of Labour and Social Welfare conducts workshops to help businesses in sectors such as manufacturing, automotive and logistics integrate AI and robotics safely, with a focus on accident prevention and mental health risks in digital work environments[130].
- In Saudi Arabia, the Sixth Saudi Global Conference for Occupational Safety and Health (May 2024)[131], sponsored by the Ministry of Human Resources and Social Development, focused on the implications of technological transformation for OSH.
- In South Africa, the Future of Work Safety Initiative[132] promotes the safe adoption of AI and automation in industries such as mining and manufacturing.
- In the United States of America, NIOSH has released several reports on AI and automation's role in OSH, discussing risks related to robotics and AI-driven workplace systems[133]. It also produced a webinar on "The Role of Artificial Intelligence in the Future of Work."[134] The US National Safety Council and Safetytech Accelerator have co-authored a report on AI-powered solutions for musculoskeletal disorder prevention[135].

125 Introducing New Technology at the Workplace
126 Robots and Cobots
127 Exoskeletons
128 Ministry of Economic Affairs and Employment, Finland.
129 Ministry of Labour and Employment – Workplace Safety
130 Mexico revises regulations to improve machinery safety
131 The Minister of Human Resources and Social Development Inaugurates the Global Conference for Occupational Safety and Health Under the Theme Scanning the Horizon
132 Department: Employment and Labour, Republic of South Africa
133 Occupational Safety and Health Equity Impacts of Artificial Intelligence: A Scoping Review
134 The Role of Artificial Intelligence in the Future of Work
135 https://safetytechaccelerator.org/downloads/report-emerging-technologies-for-the-prevention-of-msd/

Employers' organizations are also actively promoting responsible digital technology integration, organizing awareness-raising events and producing reports and guides.

- The Unión Industrial Argentina promotes the "Ruta X" programme[136], which supports digital transformation, particularly in SMEs. The programme features the Centro de Industria X[137], which hosts workshops on digital transformation and acceleration, showcasing innovative OSH solutions such as AI-powered risk detection.
- In Brazil, the National Confederation of Industry promotes digital transformation and supports companies in navigating the associated risks.[138]
- In Chile, the Confederation of Production and Commerce, following the establishment of a Digital Transformation and Artificial Intelligence Roundtable, has developed proposals to address the challenges in this area, with a focus on training, productivity and collaboration.[139]
- The Hungarian Confederation of Employers and Industrialists conducted a survey on labour and skills supply, highlighting the need for workforce training in digital competencies to prepare for the digital transition.[140]
- The Employers' Confederation of the Mexican Republic advocates responsible AI and digital technology adoption, focusing on education and digital skills training.[141]
- In Ireland, the Irish Business and Employers Confederation hosted the seminar "Embracing Technology for Managing OSH"[142], focusing on digital solutions, compliance and policy, while sharing case studies and best practice. The Industrial Minerals Association also held a seminar in 2024 on "Dust Exposure Monitoring and Health and Safety in the Digital Age"[143].
- In Italy, Confindustria Brescia held a meeting on "Artificial intelligence and SMEs: experiences from a present future",[144] part of a national roadshow engaging 700 companies on digitalization.

Trade unions are actively leading awareness-raising campaigns and developing resources to ensure that worker safety and health remain a priority in the adoption of new technologies. Their efforts focus on promoting a digital transition that upholds workers' rights, creating safer, healthier and more inclusive workplaces in an evolving technological landscape.

- In Argentina, the "SinDigital" project provided valuable insights, publishing the report Technology and Digital Transformation: A Challenge for Trade Unions[145]. A survey of 27 organizations representing 1.3 million workers examined the impact of digitalization on labour conditions and union operations, including how digital tools affect data management within unions.
- In Colombia, the Asociación Nacional de Profesionales de Salud, Seguridad y Ambiente launched a series of podcasts on AI's role in transforming OSH, focusing on topics such as digitalizing OSH with AI, creating a safety culture and managing technological risks in the workplace.[146]
- In Germany, IG Metall advocates ethical use of AI in manufacturing, emphasizing worker involvement in technology deployment and algorithmic risk awareness[147]. Additionally, UNI Global Union published Algorithmic Management - Awareness, Risks and Response of the Social Partners [148], urging unions to increase capacity and collaboration to improve coverage of risky AM in collective agreements.

136 https://www.uia.org.ar/ciencia-tecnologia-e-innovacion/3880/agenda-40-la-uia-lanzo-ruta-x-x/
137 https://rutax.uia.org.ar/centroX
138 Especialista orienta sindicatos sobre comunicação digital
139 https://www.cpc.cl/desafio-transformacion-digital/?lang=es
140 Labour and skills supply in different regions of Hungary - trends and challenges
141 COPARMEX's "Connecting Mexico" Project
142 Embracing technology for managing occupational safety and health
143 IMA-Europe 2024 OSH Seminar: Dust Exposure Monitoring and Health and Safety in the Digital Age
144 Artificial intelligence and SMEs: experiences from a present future
145 'Technology and digital transformation: A challenge for trade unions
146 Digitalizando la SST con IA; Transformación IA buscando una cultura de Seguridad; Inteligencia Artificial en el mundo de la SST
147 Promoting human-centred AI in the workplace. Trade unions and their strategies for regulating the use of AI in Germany
148 Algorithmic Management - Awareness, Risks and Response of the Social Partners

- The Trade Union Congress of the Philippines launched campaigns addressing digitalization's impact on job security and OSH, advocating for national AI regulations that protect workers' rights[149]. Its training programmes promote safe practices with AI, helping workers adapt to automation and digital environments.
- In Spain, the Comisiones Obreras and the Unión General de Trabajadores, have produced reports to support collective bargaining and educate work councils on issues related to algorithms and data protection. The latter also published the report Trade Unions in the Digital Age: Country Fiche on Spanish Manufacturing Sector,[150] focusing on digital skills training for workers and unions.
- In the United Kingdom of Great Britain and Northern Ireland, Trades Union Congress published the report Shaping Our Digital Future[151] exploring collective bargaining on technology and emphasizing the need to protect workers from the excessive performance pressures and constant monitoring often associated with AI-driven work environments. This is part of the broader Dignity at Work and the AI Revolution manifesto, [152] which advocates for fair and transparent AI use, highlighting concerns over job security, work conditions and mental health.

2.3.5 Training programmes

In many countries, public authorities and other bodies have developed training programmes to help employers and workers address the risks associated with digital technologies in the workplace. Some initiatives cover digital technologies in general, while others focus specifically on AI, often in combination with robotics or automation, and target specific sectors, such as manufacturing, mining and energy.

149 Towards building worker and trade union in the Philippines
150 Trade Unions in the Digital Age: Country Fiche on Spanish Manufacturing Sector
151 Shaping our digital Future
152 Dignity at Work and the AI Revolution - A TUC manifesto

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- In Brazil, the Social Service of Industry [153] offers training in industries undergoing digital transformation, focusing on safe interactions with robots, AI and other digital tools. Its programmes emphasize the ergonomic risks of automation and AI, as well as the mental health impacts of increased digitalization.
- In Canada, Workplace Safety and Prevention Services [154] offers digital safety training, particularly in sectors such as manufacturing, construction and agriculture. The focus is on risks associated with AI and robotics, including ergonomic concerns and the psychological impact of digital technologies.
- Safe Work Australia[155] also provides training for workers and employers in sectors such as construction, logistics and manufacturing. The programmes focus on safe interaction with AI-driven tools and robotic systems, and continuous skills development in response to digital transformation.
- In Chile, the Commission of the National System for Certification of Labour Competencies - ChileValora,[156] provides training to workers in high-risk sectors such as mining, manufacturing and energy. The training covers safety protocols for AI and robotics, as well as the psychological effects of digital transformation.
- The United Arab Emirates "National Program for Artificial Intelligence"[157] provides training to enhance AI skills among public sector employees, ensuring they are equipped to manage AI integration in their respective sectors.
- In Poland, the Central Institute for Labour Protection[158] conducts training on the safe integration of AI and robotics into industries such as manufacturing, logistics and healthcare. This training addresses robotic safety, the integration of AI into risk assessments and the importance of ergonomics, alongside efforts to mitigate psychosocial risks and promote mental health in the digital workplace.
- In Singapore, the Workplace Safety and Health Council[159] offers certification programmes aimed at businesses to understand the safety impacts of digital transformation, especially in high-risk sectors such as construction and logistics. The training focuses on the safe deployment of AI systems, robotics and wearable devices for safety monitoring, as well as addressing the psychological effects of automation.

2.3.6 Research on the OSH implications of digitalization

Research initiatives are crucial for understanding and addressing the evolving challenges in workplace safety and health. Research plays a key role in providing governments, employers and workers with reliable information about the impact of digital technologies. This enables them to identify priorities and take informed action to promote and protect workers' safety and health. Several initiatives focusing on different aspects of workplace digitalization have emerged, including grants, PhD programmes and academic conferences that foster collaboration and expand knowledge in this area.

- In Austria, the Work NEW 4.0 initiative[160], led by the Austrian Federal Ministry of Labour and Economy, focuses on the impact of digitalization, automation and AI on OSH. This initiative explores both the benefits, such as AI-driven safety monitoring, and the challenges, including mental health concerns and job displacement. It encourages collaboration between academics, businesses and government agencies to ensure the safe integration of these technologies.
- In Canada, the Institut de recherche Robert-Sauvé en santé et en sécurité du travail has launched the regular publication Bulletin de Veille Scientifique sur l'Intelligence Artificielle et la SST.[161] This initiative aims to provide stakeholders with research insights into emerging technologies, their implications for workplace safety, and potential strategies for integrating AI to enhance OSH practices.

153 Social Service of Industry (SESI)
154 Workplace Safety and Prevention Services (WSPS)
155 Safe Work Australia
156 ChileValora
157 https://u.ae/en/information-and-services/jobs/training-and-development/online-training/national-program-for-artificial-intelligence
158 Central Institute for Labour Protection
159 Workplace Safety and Health (WSH) Council
160 https://lab.neos.eu/_Resources/Persistent/a7b52188459eaf6028338e8958683de074b3324f/ELF%20-%20Work%204.0.pdf
161 Nouvelle veille dédiée à l'intelligence artificielle en SST > IRSST : Institut de recherche Robert-Sauvé en santé et en sécurité du travail

- In Chile, the Social Security Superintendence Authority funds research on the use of AI and wearable devices for real-time safety monitoring, focusing on industries such as mining, forestry and agriculture,[162] with the application of AI for biomechanical assessment of gait using conventional video cameras,[163] digital advice on risk management[164] and the effectiveness of virtual reality programmes to promote risk prevention.[165]
- New Zealand's Robotics, Automation, and Sensing[166] network brings together experts to discuss the safety implications of robotics and automation, organizing conferences that explore the future of work and worker safety in a digitalized world.
- In Sweden, the New World of Work[167] research group at the Karolinska Institute investigates how algorithmic systems impact worker health, safety and wellbeing, also considering the negotiations between workers and employers when implementing such technologies.
- In the United States of America NIOSH supports AI and robotics research to improve workplace safety. NIOSH offers grants for projects using AI to predict accidents, automate safety protocols and make ergonomic adjustments. They also fund research on AI-driven systems, such as exoskeletons, to reduce injury risks, as well as machine learning applications to analyse safety data.[168]

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163 https://www.suseso.cl/619/w3-article-732234.html
164 https://www.suseso.cl/619/w3-article-732253.html
165 https://www.suseso.cl/619/articles-672238_archivo_01.pdf
166 https://www.nzras.org.nz/
167 https://ki.se/en/research/research-areas-centres-and-networks/research-groups/the-new-world-of-work-theo-bodins-research-group
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2.4 Managing digitalization and OSH at the workplace

Effective workplace-level action, with active worker participation, is critical to ensuring that the design and implementation of new technologies into workplaces enhances OSH. As new technologies reshape the nature of work, workplaces must implement targeted measures to address emerging risks. These measures must be carefully tailored to the specific needs of the workforce and the challenges posed by technological advancements. By adopting proactive strategies, companies can ensure that technology strengthens, rather than compromises, worker safety and well-being.

At workplace level, digitalization can introduce significant changes, such as those related to automation or digital monitoring. Maximizing opportunities and addressing challenges requires a collaborative approach where workers and their representatives are actively engaged in the development of measures and solutions. Workers should be involved at every stage of new technology implementation, including its selection, defining its role and purpose, introduction, and ongoing review. Through dialogue and collaboration, workers and employers can work together to develop strategies for the safe use of digital technologies, helping ensure these advancements support worker health and safety.

To this end, establishing robust OSH management systems is essential for proactively addressing the risks introduced by digitalization and AI.

2.4.1 Implementing a comprehensive OSH management system

As organizations integrate digital tools, AI and automation into their operations, a robust OSH management system ensures that safety and health are prioritized, while also adapting to technological advancements. This should be implemented in consultation with workers and their representatives at all stages. In line with the ILO OSH 2001 Guidelines on Occupational Safety and Health Management Systems, this system includes the following key elements:

- **Policy Development:** Formulating a clear OSH policy that reflects the organization's commitment to safety and health, including in the context of integrating new technologies and introducing new processes. This should be agreed through a tripartite process, adhering to the provisions contained in Convention No. 155 throughout.
- **Organizing:** Defining roles and responsibilities for OSH, ensuring management commitment and promoting active worker participation and consultation, particularly regarding the integration of new technologies and related OSH measures.
- **Planning and Implementation:** Systematically identifying hazards and assessing all risks, including those associated with new technologies, including AI and digital tools, and implementing preventive and protective measures tailored to these innovations.
- **Evaluation:** Monitoring and measuring OSH performance, including the effectiveness of controls related to new technologies, and conducting regular audits to ensure compliance with OSH standards.
- **Action for Improvement**: Implementing corrective actions based on evaluations and striving for continual improvement. This includes revising OSH policies and procedures to address the evolving risks posed by technology-driven changes in the workplace.

2.4.2 Consulting, informing and training workers

Ensuring that workers are well informed about new technologies and their potential risks, and are actively involved in implementing preventive measures, is crucial for a safe and healthy working environment.

As outlined in Convention No. 155, workers and their representatives should be meaningfully consulted before the introduction of new technologies impacting OSH, ensuring they have a voice in decisions that directly affect their work. This consultation should be proactive, with opportunities for workers to express concerns, provide feedback and influence decisions about how new technologies are implemented

and managed in the workplace. Research indicates that active worker participation in decision-making processes can improve both safety outcomes and the acceptance of new technologies (EU-OSHA 2024b).

Consultation and participation also help workers feel more confident and supported when adapting to new systems. The expertise and knowledge of workers and their unions is also critical to creating the best solutions. Their involvement can help identify risks that may not be obvious during the planning or design stages and ensure that solutions are tailored to the real-world needs of the workforce. This approach promotes a positive OSH culture, where workers are not only trained but also engaged and take responsibility in shaping their working environments. Additionally, employers should ensure that consultation processes are inclusive, considering the different needs of the workforce. A culture of worker consultation and participation also encourages reporting of potential risks without fear of retaliation, helping to identify and address issues promptly and effectively. By making workers partners in the process, employers foster an environment where safety and well-being are shared priorities.

To ensure meaningful worker participation and the safe implementation of digital technologies, employers should provide comprehensive, ongoing training that equips workers with adequate knowledge and skills. This includes understanding operating procedures, recognizing potential hazards, applying preventive measures and knowing how to respond during malfunctions or emergencies. Training should be an ongoing process, tailored to accommodate updates in technology and changes in work practices. Employers should ensure that training materials are accessible and comprehensible to all workers, taking into account factors such as language diversity and varying levels of literacy.

2.4.3 Addressing new and emerging risks through sound risk assessment

Integrating new technologies into the workplace necessitates a thorough OSH risk assessment, with full worker participation. This extends beyond evaluating the physical workplace and equipment - such as wearable devices, robots and machinery - to also addressing risks associated with digitalized processes, including AM, smart monitoring systems and automation.

Risk management involves identifying potential hazards, assessing the likelihood and severity of associated risks and determining appropriate control measures to mitigate them, following the hierarchy of controls. This assessment must account for the complexities of emerging technologies, as algorithmic systems and automation pose significant challenges due to their evolving nature. Risk assessments should not only focus on technologies directly related to work or production processes but also on those designed to improve OSH, as they may inadvertently introduce new risks, particularly psychosocial ones.

As technology evolves, so do workplace risks. New software updates, system upgrades or changes in work processes can introduce unforeseen hazards, necessitating continuous review and adaptation of OSH preventive measures. To address these risks proactively, employers should conduct risk assessments regularly and whenever the introduction of new technology is planned. This approach enables enterprises to identify and implement appropriate preventive measures promptly, ensuring a safer transition to digitalized work environments. Staying informed about technological advancements and regulatory changes, as well as gathering feedback from workers further enhances the ability to detect and address emerging risks effectively.

Digital technologies can enhance the risk assessment process by providing real-time data, simulations and predictive analytics. Digital risk assessment tools, such as AI-driven hazard detection systems, wearable sensors and advanced data analysis platforms, can help anticipate potential risks before they manifest. However, while these digital tools offer valuable insights, they should not replace human oversight. It is essential to integrate technological assessments with expert judgement, worker consultation and contextual understanding to ensure comprehensive and accurate risk evaluations. Relying solely on digital assessments may lead to blind spots, particularly concerning psychosocial risks and the broader impact of technological change on work organization. By combining human expertise and digital tools in OSH risk assessments, workplaces can adopt a balanced, proactive approach to managing risks associated with emerging technologies.

Importantly, employers should actively involve workers and their representatives in the risk assessment process. Their insights and experiences are invaluable in identifying risks that may not be immediately apparent, particularly those related to psychosocial factors and work organization. Workers' feedback ensures that the risk assessment is both comprehensive and relevant to those directly affected by technological changes. This participatory approach also fosters a sense of ownership and cooperation, leading to more effective implementation of mitigation measures.

Integrating new technologies into *risk management for improved OSH*

AI-enabled systems are transforming the traditional approach to risk assessment in the workplace due to their ability to detect, analyse and react to threats swiftly. By examining vast amounts of data from various sources, including sensor networks, wearable devices and historical incident records, AI algorithms can identify potential hazards and predict risks in real-time (O'Brien 2023). This proactive risk assessment allows for timely interventions and preventive measures to minimize accidents and injuries (Safetytech Accelerator 2024).

Innovation technologies play a key role in risk prevention and control. As with all workplace preventive measures, these should be implemented according to the hierarchy of controls. An example of how innovative technologies can be applied according to the hierarchy is shown below.

		Confined spaces	Musculoskeletal disorders	Work sites
More effective ↕ Less effective	**Elimination** Physically remove the hazard	Replace physical entry with drones or robotic crawlers	Robotic process automation for repetitive work	Robotics to remove workers from hazardous tasks and environments
	Substitution Replace the hazard	Immersive virtual reality simulations for skill development	Exoskeletons to ease heavy manual handling Collaborative robots to share workload	Nano-engineered materials to replace hazardous substance with safer alternatives
	Engineering controls Isolate people from the hazard	Real-time monitoring systems for continuous tracking of environmental conditions inside confined spaces	Computer vision to identify ergonomic risks	Sensors and wearable devices to monitor worker exposures to hazards in real time
	Administrative controls Change the way people work	Digital work permit systems for assessment and authorization before entry	Gamification and simulation of ergonomic training to engage and educate workers on best practices	VR and AR training for hazard recognition and emergency response
	PPE Protect the worker with PPE	Wearable gas detectors for continuous monitoring and immediate alerts	Smart PPE with built-in sensors to detect and warn of incorrect posture or overexertion	Smart PPE with embedded sensors to monitor worker vital signs

Source: Safetytech Accelerator (2024)

Key takeaways

Digitalization is reshaping the world of work, offering new opportunities for OSH.

- Digitalization can enhance OSH by reducing hazardous exposures, improving risk detection and prevention, streamlining processes and optimizing work organization to minimize both physical and mental workloads, among other benefits.

The integration of digital technologies can also introduce new physical, organizational and psychosocial risks, which must be carefully assessed and managed.

Automation can significantly enhance workplace safety and health by reducing hazardous exposures.

- Advanced robotics can remove workers from hazardous tasks and dangerous environments, such as high-risk operational areas or situations exposing workers to extreme temperatures or toxic substances.
- Robots and exoskeletons can support workers in physically demanding jobs, minimizing musculoskeletal disorders and enhancing overall safety.
- Automation can eliminate repetitive and monotonous tasks, such as in factory production lines as well as in administrative work, including form-filling and processing applications, allowing workers to focus on more complex and engaging responsibilities.

While beneficial, automation can also introduce risks, including mechanical failures, ergonomic challenges, chemical exposure, noise hazards and psychosocial risks such as job intensification, cognitive overload, social isolation and job insecurity.

Smart OSH tools and monitoring systems improve risk detection and response, through real-time data and predictive analytics.

- Wearable devices, sensors and AI-driven systems detect hazards such as poor air quality, excessive noise exposure and ergonomic risks, preventing accidents and improving worker health.
- Predictive analytics enhance safety and health at work by identifying hazards early, enabling proactive interventions and reducing workplace injuries.

Smart wearable devices, including smart PPE, support worker safety, health and well-being but issues related to comfort, usability and proper fit - especially across diverse worker populations - must be addressed to ensure effectiveness.

Privacy concerns, workplace surveillance and stress from continuous monitoring need to be considered when adopting these systems.

Extended reality technologies revolutionize OSH training and hazard awareness.

- Virtual reality and augmented reality provide immersive, risk-free training for high-hazard environments, improving skills retention and emergency preparedness.
- Virtual simulations can support workplace inspections, hazard identification and ergonomic assessments, reducing on-site risks.

To ensure the safe use of these technologies, potential risks such as blocked visibility, balance issues, visual strain and cognitive overload must be carefully assessed and managed.

The growing use of algorithmic management is reshaping workplace dynamics, influencing how tasks are assigned, monitored and evaluated.

- Algorithmic management systems optimize scheduling, workload distribution and task allocation, improving efficiency and work-life balance.
- Excessive surveillance, productivity pressure and automated decision-making can reduce worker autonomy and increase stress. Other potential psychosocial risks associated with algorithmic management include social isolation, bias in hiring and promotions and intrusive data collection.

The shift to online work, remote arrangements and digital labour platforms is reshaping how and where work is performed.

- Remote and hybrid work (telework) and platform work enhance flexibility, work-life balance and inclusion, benefiting workers with caregiving responsibilities, disabilities or mobility restrictions.

Telework and platform work can lead to increased workload, digital surveillance, social isolation and ergonomic risks. Platform workers also often face job insecurity, lack of OSH and social protections and irregular work schedules, impacting their health and well-being.

The creation, operation and disposal of digital technologies rely on a vast workforce, raising critical OSH and environmental concerns.

- Workers in data annotation, content moderation and AI development face high workloads, psychological strain and surveillance, often without adequate protections.
- Workers involved in technology production and waste management often face serious OSH risks, including miners extracting critical minerals like cobalt and lithium in hazardous environments, factory workers enduring long hours under unsafe conditions, and informal e-waste workers exposed to toxic chemicals.
- While AI and automation can improve safety in production and recycling, their growing energy demands and environmental footprint must be addressed to ensure both worker protections and sustainable practices.

A balanced and interdisciplinary approach is essential to ensure OSH in the digital age.

- Existing OSH frameworks remain essential for addressing emerging risks from digitalization. For instance, the ILO's OSH instruments are key to ensuring the fundamental right to a safe and healthy working environment, including in the digital era.

- National policies and strategies are increasingly addressing the OSH implications of digitalization, ensuring that workers are protected in evolving work environments and promoting a responsible digital transition to balance innovation with worker protections.
- Regulations addressing OSH risks from digital technologies are evolving, with new measures covering robotic safety and human-robot interaction, the right to disconnect, algorithmic management, telework and platform work, while collective bargaining agreements help safeguard worker protections in digitalized workplaces.
- Voluntary standards and guidelines, awareness campaigns and training initiatives play a crucial role in ensuring the safe and healthy use of technology by promoting compliance, guiding businesses and equipping workers with the necessary digital skills to navigate technological change.
- The social partners play a key role in shaping digitalization policies by participating in decision-making, negotiating collective agreements and leading awareness-raising initiatives to promote fair and safe technology adoption.

Risk assessment and management is essential to ensuring a proactive approach to prevent potential new risks.

- Risk assessment should be regularly conducted to identify hazards associated with digital technologies, considering physical, organizational and psychosocial risks.
- The hierarchy of controls should guide preventive measures, prioritizing hazard elimination and engineering solutions over administrative controls and PPE, ensuring that technology is used for the enhancement of worker safety and health rather than as a substitute for robust OSH protections.
- Digital tools such as AI-driven analytics, real-time monitoring systems and predictive modelling can enhance risk assessments and improve workplace safety strategies, but they should complement - not replace - human judgement in OSH practices.
- Preventive and control measures should be adapted to the needs of specific worker populations, ensuring that digital technologies provide opportunities for all while mitigating risks for those more vulnerable to OSH challenges.
- Workers should be actively involved in all stages of digital technology implementation, shaping their design, operation and control, ensuring their perspectives are considered and that digitalization supports rather than undermines OSH.
- Comprehensive training programmes should equip workers with the necessary skills to use new technologies safely, recognize potential risks and respond effectively to emerging hazards, with tailored training for those in high-risk or digitally intensive roles.
- Continuous evaluation and adaptation of workplace OSH policies should ensure they remain relevant as technology evolves, incorporating worker feedback and the latest safety advancements.

Further research is needed to understand the long-term OSH impacts of digital technologies and ensure informed implementation.

- There is a need for more data on both the potential benefits and negative OSH impacts across sectors— such as the decrease or increase in work-related injuries and diseases.
- More collaboration between governments, academia and the social partners is needed to address research gaps and support evidence-informed strategies to ensure safe and healthy digitalized workplaces.

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