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# TOWARDS AN AI-AUGMENTED, HUMAN-CENTRED SMART DIGITAL ECOSYSTEM IN OCCUPATIONAL HEALTH AND SAFETY

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*SUMMARY: Artificial Intelligence (AI) is reshaping occupational health and safety (OHS), shifting prevention models, risk assessment, and organisational processes. While traditional safety systems rely on reactive approaches and post-event analyses, AI enables predictive, adaptive, and data-driven prevention based on continuous monitoring and machine learning. The integration of sensor technologies, computer vision, and intelligent personal protective equipment supports early detection of biomechanical risks, fatigue, unsafe behaviours, and environmental hazards. Furthermore, AI enhances the structuring and linkage of occupational electronic health records, integrating biometric, behavioural, and environmental information while ensuring compliance with privacy-by-design principles through advanced Privacy Enhancing Technologies. A human-centred digital ecosystem is proposed, founded on three pillars - technical-predictive, organisational-decision-making, and ethical-social - to ensure transparency, fairness, and sustainability in AI adoption. The role of occupational physicians is reassessed considering emerging digital competencies and ethical requirements, emphasising that AI should augment, rather than replace, professional expertise. A successful digital transition requires continuous dialogue among stakeholders, updated ethical frameworks, and robust interdisciplinary cooperation to place human health, dignity, and rights at the core of technological innovation.*

**Key words:** *artificial intelligence, occupational health and safety, human-centred smart digital ecosystem*

## INTRODUCTION

The relationship between technological progress and work has been a central theme in social and economic analysis since the second half of the eighteenth century, coinciding with the first industrial revolution. Every wave of innovation - from James Watt's steam engine to the first electronic computer, the Electronic Numerical Integrator and Computer (ENIAC) - has generated both fears and expectations regarding its impact on the world of work and on social structures. The current phase of the digital revolution, characterised by the widespread diffusion of Artificial Intelligence (AI), stands out for the speed and pervasiveness with which it is infiltrating productive processes and services. AI is not merely a tool, but a transformative technology capable of redefining the governance of workplace health and safety (WHS), resulting in a genuine Kuhnian paradigm shift.

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Braverman *(Labour and Monopoly Capital, Monthly Review Press, 1974)* highlighted how technology could reduce workers' autonomy through the standardisation - an early form of automation - of tasks, invoking the so-called Babbage principle *(On the Economy of Machinery and Manufactures, Cambridge University Press, 2009)*. Decades later, analyses by the Joint Research Centre *(Fernández-Macías et al., 2025)* confirm that the impact of technology does not affect only the quantity of employment, but above all its quality and the redefinition of management structures. AI introduces the possibility of automating not only manual tasks but also cognitive activities, radically reshaping the employment landscape and opening new perspectives for proactive, predictive, and data-driven risk management, real-time monitoring, and optimisation of decision-making processes, based on Machine Learning (ML), Deep Learning (DL), Large Language Models (LLMs), Natural Language Processing (NLP), and Expert Systems (ES).

This new technological frontier, while transforming the nature of work, may also generate risks relating to deskilling, technology-related stress (so-called technostress), and a loss of meaning in work. Human resource (HR) management processes may be distorted by pre-existing biases, as algorithms trained on socially biased data tend to reproduce and sometimes amplify such biases on a large scale.

The adoption of AI in traditional workplaces, such as logistics sorting centres, may lead to working environments characterised by algorithmic management and surveillance, and by standardisation of tasks. Workers may be subjected to constant monitoring and their performance evaluated by algorithms, reducing their autonomy - echoing the phenomenon of the platformisation of work, in which the control logic typical of digital platforms (gig economy) extends into conventional workplaces.

As noted by European and international bodies, the implementation of digital technologies, and AI in particular, does not produce predetermined effects. A correct understanding of this phenomenon is essential to effectively adapt to future challenges, minimising risks and maximising opportunities through careful regulation and standardisation by stakeholders. Their attention must also encompass ethical considerations, as addressed separately, following guidance from bodies such as the World Health Organization (WHO), the International Labour Organization (ILO), and the European Trade Union Institute (ETUI). These organisations have identified ethical and regulatory frameworks, such as so-called Explainable AI (XAI), emphasising that this technology is intended to "support work rather than replace it".

## AI as the Core Driver of a Human-Centred Digital Ecosystem

Most current prevention systems are based on reactive and linear models centred on post-event analysis and statistical categorisation of incidents. AI, by contrast, promotes predictive and adaptive prevention based on continuous data flows, continuous learning models, and self-calibration capabilities, enabling the development of a human-centred digital ecosystem based on AI.




*Figure 1. AI-Driven Risk Assessment and Management in Banking: Balancing Innovation and Security*

*Slika 1. Procjena i upravljanje rizikom u bankarstvu uz pomoć umjetne inteligencije: ravnoteža između inovacija i sigurnosti*

This transformation entails a synthesis of technology, organisation, and ethics, whereby safety becomes not only a regulatory obligation but an emergent property of the interaction between cognitive systems (human and artificial) and complex production environments.

A review of the most recent literature describes a dynamic and adaptive system capable of integrating, in real time, data flows from environmental and personal monitoring sensors, potentially combined with health data, to produce updated and personalised risk predictions.

This system rests on three pillars:

- technical-predictive, centred on automated processing of environmental and behavioural data;
- organisational-decision-making, relying on decision-support systems for risk management;
- ethical-social, assessing the sustainability, transparency, and fairness of AI systems.




*Figure 2. The three pillars of the AI-Augmented human-centric ecosystem*

*Slika 2. Tri stupa ekosustava usmjerenog na čovjeka i obogaćenog umjetnom inteligencijom*

The implementation of AI as a tool for improved WHS management is now widespread and heterogeneous across the primary, secondary, and tertiary sectors. Technologies based on computer vision and particularly motion analysis enable assessment of the risk associated with awkward postures using work sampling, while simultaneously notifying workers, through Internet-of-Things (IoT) wearables, when risk thresholds are exceeded. Computer vision combined with Convolutional Neural Networks (CNNs), and certain "smart" personal protective equipment (PPE) equipped with wearables linked to Recurrent Neural Networks (RNNs), allows identification of fatigue, distraction, and drowsiness through the integration of biometric signals (EEG, eye-tracking), environmental parameters, and behavioural indicators. These systems also enable detection of incorrect PPE usage and proximity to hazardous zones or dangerous machinery.

AI can also be used to enhance the management of Occupational Health Records and risk documentation (Electronic Health Records – EHRs), which currently often contain unstructured data, enabling integration with data generated by wearables and environmental sensors, akin to Patient-Generated Health Data (PGHD), as well as data concerning social and behavioural determinants of health (SBDH), accessible through record linkage. This must occur in compliance with health data protection norms and the principle of privacy by design, enabled by state-of-the-art Privacy Enhancing Technologies (PETs), classified by the OECD into Data Obfuscation Tools, Encrypted Data Processing Tools, Federated and Distributed Analytics, and Data Accountability Tools.

AI is further applied to predictive maintenance, anomaly detection in work processes, and simulation of controlled risk scenarios through digital twins, adaptive simulation models that replicate the working environment. All collected data may then be integrated into unified platforms to produce real-time global analyses of WHS. According to the ILO Global Report 2025, digitalisation is already transforming WHS, shifting the focus towards predictive and personalised approaches. In order to translate the proposed conceptual framework into practical organizational strategies, it is necessary to consider how AI-supported systems may be concretely implemented in occupational health and safety contexts. For instance, in logistics centres, predictive biomechanical monitoring systems based on computer vision and convolutional neural networks (CNNs) can analyse workers' movement patterns in real time. When risk thresholds for awkward or potentially harmful postures are exceeded, these systems may provide immediate haptic feedback through IoT-enabled wearable devices, supporting preventive ergonomic interventions.

In high-precision manufacturing contexts, the integration of biometric signals, such as eye-tracking data, with environmental and operational parameters can support the monitoring of cognitive load and fatigue. Such systems enable the early detection of distraction or drowsiness, allowing proactive interventions before safety incidents occur. Similarly, AI-driven structuring of electronic health records (EHRs) may facilitate the integration of patient-generated health data (PGHD)

and information on relevant social determinants of health, allowing prevention strategies to be developed on the basis of a more holistic understanding of workers' health profiles while ensuring strict data protection through privacy-enhancing technologies (PETs).

Another promising application involves the use of digital twins and adaptive simulation models to reproduce complex work environments and test potential risk scenarios in a controlled virtual setting. These tools allow organizations to analyse anomalies and evaluate safety interventions without exposing personnel to actual hazards. Ultimately, these developments highlight that, within an AI-augmented human-centred ecosystem, occupational medicine must also reconsider the evolving role of the occupational physician, who is increasingly required to integrate digital competencies, ethical awareness, and interdisciplinary collaboration in order to effectively govern the use of AI in workplace health and safety.

## CONCLUSION

The goal of digital transition/implementation is to create an intelligent, human-centred digital ecosystem in which technology functions as an instrument for enhancing health and safety rather than an end in itself. Achieving this requires an interdisciplinary approach that actively involves workers at every stage of technological implementation.

For occupational medicine, the challenge lies in redefining the role of the occupational physician by integrating digital and ethical competencies. Careful design, integration, and training in digital skills will determine whether AI-based tools strengthen the profession or silently erode its defining expertise. Updating professional ethics codes, such as the International Commission on Occupational Health (ICOH) Code of Ethics, is imperative to address the challenges posed by AI. The future will not involve AI replacing occupational physicians, but occupational physicians capable of using AI critically and responsibly representing a further step toward safeguarding workers' health and safety.

The digital transition must be guided by continuous dialogue among all prevention stakeholders, social partners, and institutions, ensuring that human well-being, health, and rights remain at the centre.


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## LITERATURE


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## *PREMA PAMETNOM DIGITALNOM EKOSUSTAVU VEĆOM UPORABOM UMJETNE INTELIGENCIJE I SA ČOVJEKOM, ZDRAVLJEM I SIGURNOSTI U SREDIŠTU*

*SAŽETAK: Umjetna inteligencija (UI) preobražava zdravlje i sigurnost na radu (OHS), mijenjanjem modela prevencije, procjene rizika i organizacijskih procesa. Dok se tradicionalni sustavi sigurnosti oslanjaju na reaktivne pristupe i analize nakon incidenata, UI omogućuje predviđanje i adaptaciju preventivnih radnji temeljenim na podatcima dobivenim stalnim praćenjem i strojnim učenjem. Integracija senzorskih tehnologija, računalne vizije i inteligentne osobne zaštitne opreme pomažu u ranom otkrivanju biomehaničkih rizika, umora, nesigurnih ponašanja i opasnosti za okoliš. Nadalje, UI omogućava strukturiranje i elektroničko povezivanje podataka o zdravlju na radu, integriranje biometrijskih i okolišnih podataka te ponašanje na radu s fokusom na osiguravanje načela privatnosti pomoću naprednih tehnologija za povećanje privatnosti. Predlaže se digitalni ekosustav sa čovjekom u fokusu koji se oslanja na tri stupa: tehnički-predvidljiv, organizacijski-donošenje odluka i etičko-socijalni kako bi se osigurali transparentnost, fer pristup i održivost uvođenja UI. Uloga liječnika medicine rada ponovno se ocjenjuje uzimajući u obzir nove digitalne kompetencije i etičke zahtjeve, s težištem na tome da UI treba povećati a ne zamijeniti profesionalnu stručnost. Uspješna digitalna tranzicija zahtijeva trajni dijalog svih zainteresiranih, modernizirane etičke okvire i čvrstu interdisciplinarnu suradnju koji će staviti zdravlje, dostojanstvo i prava u središte tehnoloških inovacija.*

***Ključne riječi:*** *umjetna inteligencija, zdravlje i sigurnost na radu, pametan digitalni ekosustav s fokusom na čovjeka*

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