SMART DIGITAL MONITORING SYSTEMS FOR OCCUPATIONAL SAFETY AND HEALTH: OPPORTUNITIES AND CHALLENGES

The role of digital OSH monitoring systems

Digital systems and technologies are transforming the world of work for employers and workers alike. Their emergence also influences the management and improvement of workers’ occupational safety and health (OSH) in the workplace, as well as the nature, location, and organisation of work.

OSH monitoring systems are increasingly using digital technologies (ICT, cameras, wearables, smart personal protective equipment, artificial intelligence, etc.) to collect and analyse data on OSH.1

These new types of digital OSH monitoring systems offer a vast range of opportunities for substantive OSH improvements, including: enhancing workers’ safety, and health awareness; improving task and shift allocation; preventing and reducing accidents; increasing wellbeing; tailoring solutions to specific needs; decreasing occupational stress or injuries; minimising consequences of accidents; and control over decisions, etc. Despite their many known and potential benefits, new OSH monitoring systems can trigger or increase physical health and safety risks, psycho-social risks, a blurring of OSH responsibility, or certain limitations regarding training.

European workplaces are increasingly using digital OSH monitoring systems, in particular in industries in which workers are exposed to higher levels of OSH risks due to specific (hazardous) environments, but overall, their uptake continues to be relatively slow and limited.2 Factors such as the extent of technological advancement and digital transition, company size, legislation and standardisation in relation to technological changes and OSH implications, and organisational factors influence the uptake of digital OSH monitoring systems.

Notwithstanding these underlying conditions, scarcity of evidence about the use and effectiveness of these systems and the technologies they rely on constrains employers from making informed decisions about whether and which systems they can use in their organisation to improve workers’ OSH.

This policy brief discusses some of the key opportunities and challenges of the new OSH monitoring systems and outlines key takeaways for policy- and decision-makers to enhance the benefits of these systems and minimising the potential drawbacks of their use at organisational level. The policy brief draws on research findings from an EU-OSHA’s report on Digital OSH monitoring systems and OSH.

Detection and prevention of harm (proactive approach)

Digital OSH monitoring systems can support harm prevention through the collection of accurate and comprehensive data, which can be analysed and used for workplace adjustments aimed at improving workers’ OSH – for example, through measuring exposure to ergonomic hazards and identifying plant- and premises-related hazards. Digital OSH monitoring systems can also prevent harm by identifying hazardous worker behaviour and supporting personalised training to enable better use of these systems. They can also identify poor individual health and wellbeing and support online risk assessments and remote inspections. Key types of opportunities for preventing harm that OSH monitoring systems can bring to the workplace and remote locations are summarised in the table below.

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2 European Agency for Safety and Health at Work, Drivers and barriers to the adoption of new OSH monitoring systems, 2023, n.d..
### Table 1. Types of opportunities linked to the use of digital OSH monitoring systems

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<th>Examples of OSH monitoring systems and technologies</th>
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| Measuring individual or collective harmful exposure and environmental levels | Digital OSH monitoring systems can support harm prevention by measuring routine and non-routine harmful individual and collective workers’ exposure, including remotely (in sectors such as mining, tunnel construction and chemical plants). | - Wearables and smart PPE (smart glasses, hard hat sets, smart bands, smart shoes, and protective clothing, with smart electronics parts linked to smartphones and smartwatches), or heat cameras can measure individual hazardous exposure in real time (e.g. gas, mercury, UV radiation, high heat levels).  
- Badges with sensors linked to the Internet of Things (IoT) may enable the capture of radiation levels, alert workers and advise them to move away from a given area.  
- Wireless sensor networks and drones can detect harmful environmental conditions such as poisonous dust in poorly ventilated areas, explosive gases, radiation leaks, chemicals and biological agents, and high humidity. |
| Measuring exposure to ergonomic hazards | Digital OSH monitoring systems may help prevent work-related musculoskeletal disorders (WRMSDs) and repetitive strain injuries (RSIs), which may result from poor posture. This applies to different types of jobs and sectors (e.g. in offices or when teleworking, construction, mining, manufacturing, shipbuilding, agriculture, farming, waste management, hotel and restaurants, transportation and travel). | - Wearables using accelerometers, the IoT, mobile apps and exoskeletons are able to measure the number of movements, their speed, type, and appropriateness, in order to detect unsafe or harmful movements, provide real-time biofeedback to the user, and prevent long-term serious health conditions.  
- Wearables can also warn that a worker needs to stop a certain activity for which a given threshold has been reached: for instance, stopping dynamic lifting. As a result, measures can be designed to eliminate or reduce exposure to risk factors.  
- Machine-learning algorithms that use kinematic data may be used to increase reliability in distinguishing correct and incorrect postures. |

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<td>Identifying plant and premises-related hazards</td>
<td>A number of OSH monitoring systems can detect and notify workers when they are entering a hazardous area. Hazards may relate to slips, trips, and falls, forklifts, collisions and accidents when using and/or interacting with machinery or vehicles.</td>
<td>Sensors (GPS, WSN) can be used to identify proximity, measure whether speed is above safety thresholds, or activate emergency stop buttons.</td>
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<td>Identifying hazardous worker behaviour and supporting personalised training</td>
<td>Digital OSH monitoring systems also provide the opportunity to train workers on the correct use of equipment, and target and tailor training to workers whose records show that they may, on average, adopt unsafe behaviour. These systems can be applied across many different sectors, including, for instance the manufacturing, metal, construction, mining, chemical, and transport sectors.</td>
<td>CCTV, wearables, smart PPE, RFID and video cameras can be used to detect or even predict unsafe behaviour that can cause injury and also facilitate the identification of safe practices.</td>
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11 Wireless sensor networks (WSNs).


### Types of opportunities

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<td>Identifying poor individual health and wellbeing</td>
<td>• The use of accelerometers as part of the SurPASS project, which aims to <strong>evaluate an e-system that measures the daily (24/7) physical behaviour</strong> (physical activity, sedentary behaviour and sleep) at work and during the non-working time of working adults.(^{21}) Similar projects have been initiated, for instance for measuring <strong>occupational and leisure time UV radiation</strong>.(^{22})</td>
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<tr>
<td>Supporting online risk assessments and remote inspections</td>
<td>• <strong>OiRA</strong> is an EU-level online <strong>interactive risk assessment tool</strong> that enables risk forecasting.(^{24}) There are other similar comprehensive tools at national level, such as: BeSmart.ie; Rie.nl; and Prevencion10.es. There are tools for specific risk factors, such as noise or chemicals.(^{25})</td>
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<tr>
<td>Applications during the COVID-19 pandemic</td>
<td>• Sensor networks and AR enable <strong>remote inspections</strong>, for example in agriculture and forestry, oil and gas, mining and construction.(^{26})</td>
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Digital OSH monitoring systems present a range of opportunities for minimising the consequences of accidents or emergencies by enabling quick interventions and the reporting and investigation of accidents. These systems may minimise harm by signalling an emergency and sending accurate location data, suggesting to workers how

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### Minimising consequences of accidents and improving investigation and reporting (reactive approach)

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24 See: https://oiraproject.eu/en

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27 See: https://nfa.dk/da/forskning/strategiske-forskningsomraader/om-msb/om_msb_researchers


they should behave in a dangerous situation. They also help to investigate accidents quickly, safely, and effectively, and enable the reporting of accidents efficiently and with less stigma.

**Signalling and localising emergencies**

OSH monitoring systems based on GPS tracking allow workers, who would otherwise be at risk of fatality or serious harm, to be located quickly and accurately and brought to safety. This can be used, for example, for truckdrivers in distress, for firefighters entering a hazardous rescue area with fire, smoke and high temperatures, or miners and construction workers who are trapped or who have fallen.

The OSH monitoring systems allow the **automatic signalling of an emergency**, for instance through fall detection using accelerometers. They can also send automatic panic alerts, even when the worker is unable to make an emergency call. As workers can be located accurately, rescue operations can take less time.

There are new **wearable** solutions for workers in isolated working environments, which have a man-down feature integrated into a digital earpiece to use in the case of a loss of consciousness or disabling injury. Mines connected through WSNs also allow workers to be located promptly and an assessment to be made as to whether or not they are moving. This real time surveillance is made possible by Bluetooth, WiFi stations, and underground Wi-Fi or 5G. **Unmanned aerial vehicles (UAVs)** also offer significant capabilities in terms of search and rescue, both overground and underground. Autonomous drones can navigate hazards in underground mining environments or can be used in the petrochemicals industry to identify and locate victims.

**Responding to emergencies or accidents**

Digital OSH monitoring systems may also help when dealing with emergencies or accidents. **Wearables** and **AR** enable information (video, audio, images, text) to be delivered quickly and accessed easily, for example through smart glasses, so a worker can come to a more informed decision on how to best respond to the situation in which they find themselves.

In the case of firefighters, **smart PPE** has active cooling systems. While immersing the hand and forearm in cool water is the most simple and effective way to reduce heat strain, automatic cooling systems are among the preferred features for the smart PPE of the future.

**Drones** can not only provide the location of workers during search and rescue operations, it can also detect defects in equipment being used. This will be helpful for those devising ways to minimise the potential for harm, and also in delivering new equipment that may be needed, such as breathing apparatus for workers in a mining emergency.

**Accident investigation and reporting**

Digital OSH monitoring systems can support accident investigation by providing data regarding where the accident occurred, who was present, and who the victims were, what actions and/or conditions led to it, and what happened during the accident and the subsequent rescue operations (when needed). This can help to establish a chain of events.

**Accurate and unbiased accident data** can be obtained quickly and efficiently through the use of digital OSH monitoring systems, which can be sufficient for investigative purposes or can provide a good basis for further investigation, or to supplement it. Data can be gathered on exposure to various types of hazards through

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Potential challenges to the use of digital OSH monitoring systems

Despite the many recognised and potential benefits of the use of digital OSH monitoring systems, challenges remain. These arise from the potential trade-offs that must be made between the benefits and risks of these systems. Their use has implications for data collection and protection, how OSH monitoring systems work in real-life environments, working relationships, and OSH responsibilities and boundaries.

Physical risks

The use of monitoring by exoskeletons, which, by reducing pressure in some parts of the body can modify the redistribution of effort, can result in the emergence of new biomechanical constraints and risk factors for musculoskeletal disorders (MSDs). Exoskeletons might also hinder movement and lead to collisions because of their bulky structure, they may cause discomfort, skin irritation, increase cardiovascular load and stress, or make workers over-confident in their abilities, giving them a feeling of invulnerability that could result in accidents.40 VR and AR may cause disorientation, motion sickness (also called cybersickness) and eye strain, owing largely to hardware, content, and human-related factors.41

Challenges related to how OSH monitoring systems work in real-life environments

Even when technologies are certified, their accuracy for collecting accurate data is first assessed in laboratory-type environments that may not accurately replicate adverse working conditions.42 This is particularly the case in working environments that may limit sensor accuracy or in settings where technologies may face unexpected challenges: for example, thermal cameras in drone systems may not be able to locate a worker.43 Human-machine interfaces (face, gestures, voice, eye movement, brain signals) could misinterpret corrupted or low-strength signals – for example due to batteries running low or interference.44

New digital technologies may malfunction. Batteries may not only be inefficient or stop working in difficult environmental situations, they may also overheat, catch fire, or explode.45 A sensor-based vest may be vulnerable to water penetrating its electrical areas, which can cause short circuits or electric shocks. UAS can be

a safety risk to workers nearby due to system malfunction or cyber-attacks. This is particularly true for semi-autonomous or autonomous UAVs not operated by humans.⁴⁶

OSH monitoring systems may also **intensify work** and thereby potentially cause harm to workers. As OSH monitoring systems have financial implications: some companies might want to combine their OSH functions with increased productivity and thus reduce costs (e.g. by dismissing or not hiring workers)⁴⁷. In such cases, an existing worker might have to deal with additional workload.

**Challenges related to data collection and protection**

Digital monitoring systems can support OSH improvements through accurate data collection and meaningful analysis of trends at aggregate levels but can also be perceived as an invasion of privacy by workers, which can be stressful, and lead to alienation at work.⁴⁸

There are a number of important questions with regards to **data privacy, ownership and security**, linked to the design and use of OSH monitoring systems, as digital devices collect vast amounts of data, which can be sensitive personal data (e.g. related to ethnic origin, health, genetic, and biometric data). Therefore, for workers and worker representatives it is important to understand who has the right to see and use the data, what type of data are collected, how they are stored and transferred to third parties, such as external service providers, and how or when data will be deleted. Further, there is also the risk of data breaches and theft. It is important for workers to understand what types of security measures are in place to protect them against unauthorised access to data and for them to be included in processes that decide the use of digital OSH monitoring systems in the workplace or in remote locations.

Another aspect to consider is the purpose for which the data are used. There are instances, for example, of digital surveillance linked to **work intensification**.⁴⁹ Workers and their representatives sometimes perceive that management is using OSH monitoring systems to increase control over workers’ performance in the context of increasingly challenging targets.⁵⁰ OSH monitoring systems for teleworkers may also include risks and challenges related to performance monitoring. On the basis of the data collected, employers may be able to know where workers are, what they are doing, how (tired) they are feeling, or whether they are sleeping. They may also be able to find out how long someone spends on a toilet break.⁵¹ This can generate anxiety and stress due to an **always-on culture** and **anticipatory surveillance fear**, for example, in cases where digital technology frequently sends alerts, warnings, and reminders, which can be stressful as it gives a sense of constant oversight.

**AI, ML, deep-learning, and algorithms** may also have **adverse effects** on workers. For example, when an accident is about to happen, AI may be tasked with making choices that may save lives, it is therefore important...
that these systems have reliable, accurate, and unbiased data; that they have adequate ‘intelligence’ to achieve complex goals; and that they are able to reduce risks without causing more harm.\(^{54}\)

For company management, the vast amount of data collected and in need of interpretation may result in cognitive overload unless the process is automated.\(^{55}\) This also applies to workers who may receive a high volume of data/content, when using VR/AR.\(^{56}\)

**Challenges related to working relationships**

The shift to algorithmic management may impact working relationships, communication, and trust. AI management can reduce contact between management and workers, as well as between co-workers. It can therefore undermine workplace connections and motivation. The reduced scope for task rotation and variety may also lead to increased job dissatisfaction, for example in the case of workers assigned to lonely, monotonous, and repetitive work. In addition, algorithmic decision-making that is not transparent and open may lead to the perception of injustice and alienation and may, as a result, curb creativity and autonomy.\(^{57}\) The use of digital OSH monitoring systems can create frustration and a fear of technology malfunctioning or not being comfortable or easily customisable.\(^{58}\)

**Blurred OSH responsibility and boundaries**

In practice, digital OSH monitoring systems may blur responsibility for OSH and the boundary between private and work life in in several ways.

- Employers may become increasingly reliant on them at the expense of other OSH measures.
- Employers may not carry out adequate risk assessments or adopt corrective measures on the basis of the data gathered through digital technology, which could create a false sense of safety at work.
- There may be more emphasis on personal OSH monitoring measures than on collective measures: collective protective measures protect all workers rather than only one at a given time, but these two levels of protective measures are complementary rather than mutually exclusive, with personal control measures adding an additional layer of protection for residual risks\(^{59}\).
- **Blurred boundaries between private and work life:** the use of wearables may blur the distinction between private and work life if data is recorded 24/7. Wearables can warn workers that they are sleep deprived and related wellbeing programmes may point to individual measures that can be taken (e.g. a better diet, going to bed early, drinking less coffee, being more physically active, etc.) when occupational (or even public health) measures may be required instead.
- **Absence of adequate training\(^{60}\)** of workers and management to enable effective use of OSH monitoring systems in the workplace can limit potential benefits and even increase the risk of harm.

**Boosting the benefits of digital OSH monitoring systems: Key takeaways for policy- and decision-makers**

Digital OSH monitoring systems can contribute extensively to identifying and assessing OSH risks, prevent and/or minimise harm, and promote occupational safety and health. They can, therefore, be an essential tool to help organisations improve workers’ OSH, safety of equipment and processes, and health management systems. Further evidence about their practical

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\(^{54}\) Eliot, L. (2020, July 27). AI ethicists clash over real-world aptness of the controversial trolley problem, but for self-driving cars it is the real deal. Forbes. [source]


\(^{56}\) Ecorys interviews conducted for this study, from November 2021 to February 2022.

\(^{57}\) European Trade Union Confederation. (2020, July 13). Resolution on the European strategies on artificial intelligence and data. [source]

\(^{58}\) ILO. (2020, March 7). If AI has human rights, some are worried that self-driving cars might turn on us. Forbes. [source]

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use and adaptation in different organisational, sectoral, and legal contexts will enable a deeper understanding of their impact on OSH, including concrete benefits and remaining challenges. Against this background, the following key takeaways are offered with a view to enhancing the benefits of digital OSH monitoring systems and minimising the potential drawbacks linked to their use.

Takeaway 1: Develop evidence-based standards within the EU digital single market that encourage take-up

The use of digital OSH monitoring systems is often driven by compliance with existing legal standards. Legislative developments, however, often lag behind technological developments. Standardisation of smart OSH monitoring systems presents a range of challenges which are acting as a potential barrier to their adoption at organisational level. Establishing standards in the EU digital single market that provide an adequate framework and boundaries but do not lag behind the fast pace of technological developments is challenging, but efforts should continue. This will provide a suitable legal environment for designers to continue to innovate and for employers to use digital OSH monitoring systems to drive OSH improvements.

Takeaway 2: Adapt digital OSH monitoring systems to companies’ and workers’ needs

Decisions to use OSH monitoring systems should also be informed by existing needs and the desire to improve workers’ safety, health and well-being at work, not just legal requirements. While generic OSH monitoring systems may prove adequate for use across some sectors or types of jobs, tailoring solutions to the workplace and workers’ needs may increase their effectiveness and maximise positive impacts. One way to increase the effectiveness of such systems is to consider specific needs at the design stage, and the potential positive and negative impacts of the adoption of digital OSH monitoring systems.

Takeaway 3: Ensure adequate support for organisations, in particular SMEs

Concrete examples of the effectiveness of these systems and how adaptations can be made to further increase their benefits would provide the necessary evidence for decision-makers to adopt such systems. This evidence is reliant on current designers and users collecting, reviewing, and publicly sharing information about the impact of OSH monitoring systems and the adaptations that enable higher effectiveness. Extensive sharing of good and promising practices could further the take-up of these systems. Such endeavours can however be costly, alongside the design and adaptation of the monitoring systems, which present significant challenges to employers, and in particular SMEs.

Public policy measures to support the design, acquisition, and evaluation of the use of digital OSH monitoring systems (attached to financial support instruments) may improve the use of these systems and strengthen the evidence base in terms of their impact in preventing or reducing OSH risks and adjustments that need to be made.

Takeaway 4: Consult relevant parties and agree how smart OSH monitoring systems are to be used (employers, worker representatives, OSH professionals)

Before OSH monitoring systems are put into place, employers, employee representatives, and OSH professionals should discuss and reach agreement on how the systems are to be used, and the employees must be properly consulted and informed. This is an essential step in order to raise awareness, secure buy-in, and enable a productive, effective and efficient use of these systems, targeted at specific OSH needs at organisational level.

Takeaway 5: Properly inform and train company management and workers in using digital OSH monitoring systems

Limited evidence about the concrete impact on workers’ OSH, and safety processes at organisational level across different sectors, types of jobs, and in countries with different OSH cultures can limit the propensity of employers to design and/or use OSH monitoring systems. This is amplified by inadequate information about short- and long-term costs necessary for
designing, implementing, and adjusting these systems. Limited evidence of the impact on OSH can equally reduce workers’ trust levels in such tools.

Adequate information and awareness-raising campaigns can contribute to a wider and deeper understanding of these tools. Workplace resources (e.g. training guides, company policies) and regular communication about the lessons learned as a result of the use of these systems can support a better understanding of the benefits and limits of these systems. They can also ensure their alignment with pre-existing risk monitoring and other risk assessment processes, such as occupational health screening.

**Takeaway 6: Digital OSH monitoring systems have limitations, which should be clearly determined and communicated**

Smart or digital OSH monitoring systems are tools to improve and promote OSH through workplace adaptations, adjustments, corrective measures, worker training, and a reinforced culture of trust and participation. Monitoring technologies can be optimised and adapted to their intended use in different organisations, but have inherent limitations related to the technology being used, the extent to which risks can be prevented or limited, how data is collected and interpreted and potential errors stemming from the process.

OSH monitoring systems provide information about predetermined parameters and are primarily aimed at supporting systems making decisions about OSH at organisational level. They do not act autonomously or replace decision-makers, given that monitoring technology cannot account for external or contextual factors that influence the interpretation of the collected data and any decisions about corrective actions.

**Takeaway 7: Consider data collection and protection implications and adequately inform workers**

Contemporary data management and analytics bring significant benefits to decision-making processes at organisational level, including those aimed at improving OSH, and can lead to more effective risk reduction at work. There is a need for clarity, transparency, and data protection protocols about how the data collected by these systems is used, what type of data is used, who can access it, for what purposes, and how robust data security is ensured.

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