SMART DIGITAL MONITORING SYSTEMS FOR OCCUPATIONAL SAFETY AND HEALTH: OPTIMISING THE UPTAKE

Trends in the uptake of digital OSH monitoring systems

New digital systems and technologies are revolutionising EU workplaces, transforming work for both workers and employers. Technologies such as artificial intelligence (AI) and machine learning (ML), wearables, smart personal protective equipment (PPE), and exoskeletons, as well as virtual and augmented reality (VR and AR), widespread connectivity, the Internet of things (IoT), and big data applications are among those that have emerged. These systems are influencing the management and monitoring of workers' safety and health and shaping workers' experiences in their daily work. Substantiating this observation, research in international organisations has found that 40% of today's human resources (HR) departments use AI applications and 70% consider this a high priority for their organisation.[1]

According to the literature, workers are increasingly being monitored by technologies and algorithms, and may eventually be managed by 'intelligent machines'. However, the constant monitoring of workers may lead to increased performance pressure, reduced person-to-person contact, and detrimental effects on workers' mental health. In particular, so-called pervasive monitoring enabled by AI-supported digital monitoring technologies may make workers feel that their privacy is threatened, and they may lose control over the content, pace and scheduling of their work. This can lead to an inability to take breaks and interact socially when desired.[2]

European data relevant to digital systems for the monitoring of OSH also suggest that while these systems are becoming more widespread in workplaces, their uptake continues to be relatively slow and limited. Evidence gathered so far suggests that industries where workers are exposed to higher levels of OSH risks due to specific environments — such as exposure to hazardous substances — or tasks that are easy to monitor, such as those in logistics, are at the forefront of the development and use of digital OSH monitoring systems.[3] Although there is very limited quantitative data available that directly indicates the uptake of digital OSH monitoring systems, proxy indicators based on ESENER-3 data provide an indication of relevant trends as follows:

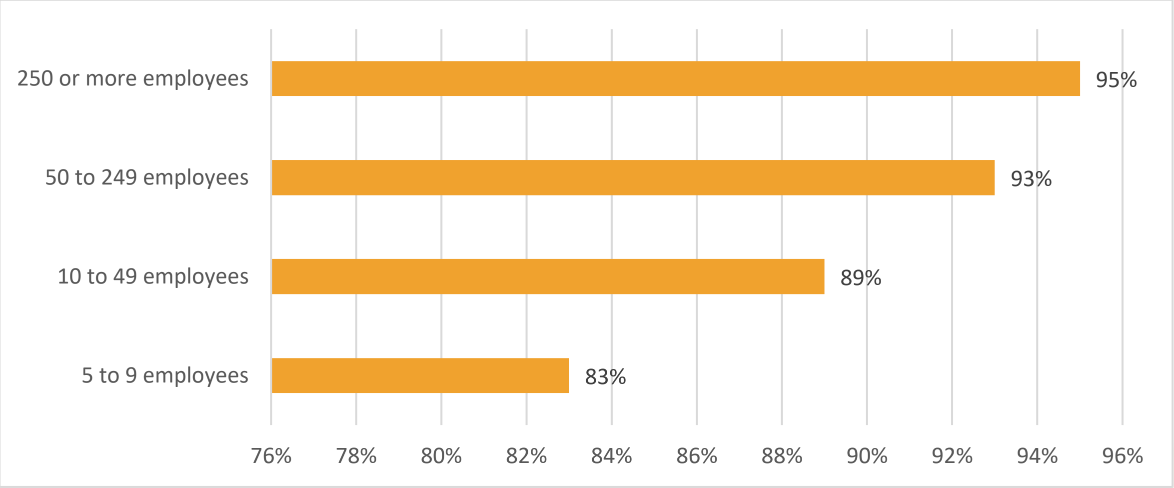
- **Establishment size appears to be a key factor influencing the uptake of digital technologies in the workplace.** Figure 1 shows a correlation between the size of the establishment and the use of digital technologies, with 95% of large companies (250 or more employees) using digital technologies compared to 83% for very small companies (five to nine employees). This may be due to larger establishments prioritising research, innovation and digitalisation to a greater extent than smaller companies. Furthermore, larger companies are more likely to possess the human resources needed to integrate new technology, which will require initiatives such as the development of staff training and accompanying manuals. Larger establishments are also more likely to have the time and resources to be able to gain a deeper insight into their organisational needs.[4]
- **There is significant variation in the uptake of the types of digital tools that enable the use of new OSH monitoring systems** among European workplaces. According to ESENER-3 results, 5% of establishments use wearable devices and 4% use collaborative robots (cobots). These figures contrast with more ubiquitous technologies such as 'PCs at fixed workplaces' (86%) and 'laptops, tablets, smartphones or other mobile devices' (77%). Further, 12% of establishments reported using

[1] https://www2.deloitte.com/us/en/insights/focus/human-capital-trends/2017/people-analytics-in-hr.html
[2] Ibid.
[3] Ecorys interviews with stakeholders from trade unions, employer representatives and research organisations, conducted between November 2021 and February 2022.
[4] Ecorys interviews with stakeholders from trade unions, employer representatives and research organisations, conducted between November 2021 and February 2022.

systems to determine the content and pace of work, and 8% used systems to monitor worker performance (rather than monitoring OSH).

- **Different sectors are embracing the digital transition to varying degrees, which may influence their receptiveness to digital OSH monitoring systems.** For example, 94% of establishments in the *Water Supply, Sewerage, Waste management and Remediation activities* sector use personal computers at fixed stations, compared to only 63% in the *Accommodation and Food service activities* sector. In the *construction* sector, 9% of European workplaces used cobots, compared to only 4% in the *manufacturing* sector.[5]

Figure 1: Use of digital technologies in establishments by size (% of workplaces) [6]



Overall, initial research suggests that digital OSH monitoring systems are still in their infancy in some cases. However, **there is an evolution towards an increased adoption** due to factors such as a heightened awareness of OSH needs and improved opportunities offered by technological sophistication. Therefore, while adoption is still limited, this is likely to increase in the near future.

Drivers and barriers to the adoption of digital OSH monitoring systems

The drivers and barriers to the adoption of digital OSH monitoring systems can be organised across three main themes:

1. Technological advancement, which includes supply-side factors;

2. Legislation and standardisation, which relates to action across these two dimensions that may bar or limit adoption; and

3. Societal and organisational factors, which are demand-side drivers and barriers.

Technological advancement

The past decade has seen a rapid improvement of digital technologies and an **acceleration of the development of digital OSH monitoring systems**. Digital technologies have become cheaper, smaller, more reliable, customisable, responsive and more comfortable to wear. Examples of this include exoskeletons and Smart PPE[7]. Digital technologies are now more interconnected, fast-paced, and more secure in terms of data collection and analysis.[8]

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[5] EU-OSHA, Third European Survey of Enterprises on New and Emerging Risks 2019 (ESENER-3), see https://esener.eu.
[6] Ibid.
[7] Most often, smart PPE combines traditional PPE (e.g. a protective garment) with electronics, such as sensors, detectors, data transfer modules, batteries, cables and other elements.
[8] Ngubo, S. A., Kruger, C. P., Hancke, G. P., & Silva, B. J. (2016). *An occupational health and safety monitoring system. IEEE 14th International Conference on Industrial Informatics (INDIN)* (pp. 966-971). IEEE. https://doi.org/10.1109/INDIN.2016.7819301

However, as new possibilities have opened up, barriers have also emerged that may hinder the widespread use of OSH monitoring systems.

- **Reliability, customisation, size, and costs** all still represent barriers as technology develops. The size and costs of monitoring systems may vary across and within technologies, which can be an obstacle to adoption because of the OSH and financial risks and challenges they still pose for both workers and employers. Khakurel et al. (2018)[9] underline it is important that safety is considered early on during the development of digital technologies, to avoid or minimise serious concerns in the workforce.
- The relatively **lengthy timeframe for the development** of new technologies in a **niche market** may constitute a **disincentive for smaller companies**, as they may lack the long-term stability and financial resources needed to invest in product development. This may include acquiring the necessary research and development expertise.
- Equally, **testing** and **certifying systems as a whole**, rather than components of a system, **is a complex and costly process**.[10] Evidence gathered from stakeholders involved in the development of sensors for OSH monitoring systems in the gas sector indicates that the testing phase is lengthy due to the complexity of measuring environmental controls such as temperature, humidity, air pressure, CO2 concentration, volatile organic compounds, and aerosol dust concentration.[11]

Legislation, standardisation and safety

In view of the technological progress and an increasingly complex world of work, policy makers are facing a challenging task to ensure relevant and effective OSH-legislation. The increased use of sub-contracting in many countries can blur liability and responsibility, and pressure for (de)regulation can exacerbate the issue. In addition, the evidence bases to support policy and practice has weakened as longstanding sources of reliable data have become inadequate. Cockburn (2021) suggests that to effectively address OSH challenges in the new world of work, social dialogue should be at the centre of legislation, enforcement and monitoring.[12]

Although the EU has a substantial body of OSH-related legislation in place,[13] the **current legislation does not specifically address the implications of technical change in OSH monitoring**, **which renders this a grey area in terms of policy and practice.[14]** However, one EU-level stakeholder interviewed for this study highlighted the delicacy of addressing this issue as changes in sensitive areas such as privacy or psychosocial risks could have a polarising effect. There are also differences between countries and industries in terms of the how risks and issues around privacy are understood. In the area of privacy and data protection specifically, the General Data Protection Regulation (GDPR)[15] provides an example of an EU-wide common legislative framework. However, scholars have pointed out that legislative gaps still allow the generation of information about a person's likely identity, attributes, interests, or personality.[16] On the technical side, some studies call for designers to base their technical considerations on privacy-aware monitoring architecture (Hu et al., 2010). However, applying this idea to systems design could reduce data accuracy.[17]

European Parliamentary Research Service. (2015). *The Internet of things. Opportunities and challenges*. https://www.europarl.europa.eu/RegData/etudes/BRIE/2015/557012/EPRS_BRI(2015)557012_EN.pdf

[9] Khakurel, J., Melkas, H., & Porras, J. (2018). Tapping into the wearable device revolution in the work environment: A systematic review. *Information Technology & People, 31*(3), 791-818. https://doi.org/10.1108/ITP-03-2017-0076

[10] EU-OSHA – European Agency for Safety and Health at Work, *Smart personal protective equipment: intelligent protection for the future*, 2020. Available at: https://osha.europa.eu/en/publications/smart-personal-protective-equipment-intelligent-protection-future

[11] Ecorys interviews with representatives of organisations involved in the development of new OSH monitoring technologies and/or systems, conducted between October and December 2021.

[12] Cockburn, W. (2021). OSH in the future: Where next? *European Journal of Workplace Innovation, 6*(1), 84-97. https://journal.uia.no/index.php/EJWI/article/view/813

[13] The OSH legal framework (OSH acquis) is composed of 24 EU directives, and in particular Directive 89/391/EEC, which define employers' obligations in relation to OSH.

[14] This gap in OSH legislation is highlighted in a 2019 briefing requested by the EMPL committee of the European Parliament, which notes that OSH Framework Directive 89/391/EEC does not 'explicitly address the new challenges posed by digital technologies'. https://www.europarl.europa.eu/RegData/etudes/BRIE/2019/638434/IPOL_BRI(2019)638434_EN.pdf

[15] Eurofound. (2020). *Employee monitoring and surveillance: The challenges of digitalisation*. Publications Office of the European Union. https://www.eurofound.europa.eu/en/publications/2020/employee-monitoring-and-surveillance-challenges-digitalisation (p. 7).

[16] Aloisi, A., & Gramano, E. (2019). Artificial intelligence is watching you at work. Digital surveillance, employee monitoring, and regulatory issues in the EU context. *Comparative Labor Law & Policy Journal, 41*(1), 95-121. https://ssrn.com/abstract=3399548

[17] Hu, H., Xu, J., and Lee, D. L. (2010). PAM: An efficient and privacy-aware monitoring framework for continuously moving objects. *IEEE Transactions on Knowledge and Data Engineering, 22*(3), 404-419. https://doi.org/10.1109/TKDE.2009.86

As regards **standardisation**, it plays an important role in creating new markets and enabling interoperability between technologies from different manufacturers using different standards (or none at all). In contrast, limited interoperability may lock end-users into a particular system,[18] discouraging market penetration, choice, competition and innovation.[19]

In particular, **safety standards are important** to help purchasers overcome information asymmetry[20] with regard to both suppliers and manufacturers, particularly in the areas of product quality (performance, capability) and safety.[21] Standardisation is critical because of the potential risks and challenges associated with new OSH monitoring systems. These systems can also have a substantial social impact in terms of the 'human in control' principle[22] that emphasises the importance of respecting human dignity and privacy,[23] and may discourage the adoption of digital solutions.

There are a number of additional barriers to the adoption of new OSH monitoring systems which further underscore the complexity of regulating and standardising these technologies, which are set out below:

- Evidence suggests that **there are very limited or no standards available in the case of many digital technologies or, conversely, that there is a proliferation of standards**. **Both situations can create barriers to adoption**.[24] For example, there are no standards in relation to Smart PPE, despite the European Committee for Standardisation (CEN) providing guidance on smart textiles.[25] Similarly, a lack of standards has been shown to hamper large-scale investments, including in the case of IoT network infrastructure. On the other hand, the European Parliament highlighted in 2019 that there are more than 600 IoT standards. According to Ranavolo et al. (2018),[26] some standards may not align with evidence-based practical guidelines, and governments should take a more proactive role defining them.
- **Digital OSH monitoring systems can be complicated due to multiple layers of regulation.** For example, the design of smart PPE must comply with traditional PPE regulation and certified electronic parts to ensure that it does not create new hazards or risks in areas such as electrical, battery, electromagnetic fields (EMF) safety, and electromagnetic compatibility (EMC). Further, standardisation bodies recognise Smart PPE as a new type of product altogether, which requires testing and the development of specific standards. For example, the presence of conductive fibres to incorporate a personal stereo into a smart raincoat might increase the risk of the wearer suffering a lightning strike during a thunderstorm, despite neither rainwear nor personal stereos, separately, needing assessment against this risk.[27]
- **Standardisation** also creates other problems. For example, in the absence of public sector intervention, standardisation may be left to private parties who in turn can be selected by industry or interest groups. This may then raise questions about the quality of the standardisation process, potentially compromising it to the disadvantage of OSH.[28]

[18] European Parliamentary Research Service. (2015). *The Internet of things. Opportunities and challenges*. https://www.europarl.europa.eu/RegData/etudes/BRIE/2015/557012/EPRS_BRI(2015)557012_EN.pdf

[19] European Parliamentary Research Service. (2019). *Standards and the digitalisation of EU industry: Economic implications and policy developments*. https://www.europarl.europa.eu/RegData/etudes/BRIE/2019/635608/EPRS_BRI(2019)635608_EN.pdf

[20] Akerlof, G. A. (1978). The market for "lemons": Quality uncertainty and the market mechanism. In P Diamond & M. Rothschild (Eds), *Uncertainty in economics. Readings and exercises* (pp. 235-251). Academic Press. Spence, M. (1973). Job market signaling. *The Quarterly Journal of Economics, 87*(3), 355-374. https://doi.org/10.2307/1882010

[21] EU-OSHA – European Agency for Safety and Health at Work, *Smart personal protective equipment: intelligent protection for the future*, 2020. Available at: https://osha.europa.eu/en/publications/smart-personal-protective-equipment-intelligent-protection-future

[22] Humans not computers and their algorithms should be responsible for any relevant decision.

[23] European Trade Union Confederation. (2016). *ETUC resolution on digitalisation: "Towards a fair digital work"*. https://www.etuc.org/en/document/etuc-resolution-digitalisation-towards-fair-digital-work

[24] Prasanna, L. D., Mangalam, S., Yuce, M. R., Beisswenger, S. C., & Lukac, M. (2017). *Internet of things : The new government to business platform - A review of opportunities, practices, and challenges*. World Bank Group. http://documents.worldbank.org/curated/en/610081509689089303/Internet-of-things-the-new-government-to-business-platform-a-review-of-opportunities-practices-and-challenges

[25] CEN/TR 16298:2011, 'Smart textiles — definitions, categorisation, applications and standardization needs'.

[26] Ranavolo, A., Draicchio, F., Varrecchia, T., Silvetti, A., & Iavicoli, S. (2018). Wearable monitoring devices for biomechanical risk assessment at work: Current status and future challenges—A systematic review. *International Journal of Environmental Research and Public Health, 15*(9), Article 2001. https://doi.org/10.3390/ijerph15092001

[27] EU-OSHA – European Agency for Safety and Health at Work, *Smart personal protective equipment: intelligent protection for the future*, 2020. Available at: https://osha.europa.eu/en/publications/smart-personal-protective-equipment-intelligent-protection-future

[28] Eurofound. (2021). *Digitisation in the workplace*. Publications Office of the European Union. https://www.eurofound.europa.eu/publications/report/2021/digitisation-in-the-workplace

Societal and organisational factors

Societal factors important to consider when examining the drivers and barriers to the adoption of new OSH monitoring systems. These factors can include economic, health and social changes, as well as changes in work practices and processes, and changes in the workforce demographics (age, gender, health, skills and education levels). For example, the proportion of migrant workers or workers having a physical or mental impairment among can create new challenges for OSH and its management. This requires both inclusive and tailored solutions.

In the case of demand-driven organisational factors, the integration of new OSH monitoring systems has significant organisational consequences for OSH management. The important aspect here is not the technology itself but rather how it is integrated into a system that is designed and implemented to respond to OSH needs in a specific context. Assessments of new systems should include the anticipated impact of the use of OSH monitoring tools on a range of OSH risk factors, as well as impacts on work processes. This ensures that hazards are removed or at least replaced by lower risk without substantially hindering productivity.

A number of key societal and organisational factors that have the potential to drive or limit the adoption of new OSH monitoring systems are set out below:

- Most recently, **the COVID-19 pandemic** has mainly been a driving force for the development of new OSH monitoring systems as companies were obliged to address exposure to biological agents by ensuring safe processes and behaviours. Additionally, the pandemic has resulted in a significant **increase in telework**, which has created new OSH hazards associated with home workstations, such as repetitive strain injuries. Employers have also grappled with the difficulty of ensuring adequate controls in relation to teleworkers.[29] Recognising the limits of OSH monitoring systems in relation to teleworking, the European Parliament passed a resolution in January 2021 that enables those who work digitally to disconnect outside of working hours.[30]
- **Needs and motivations on the part of companies and workers** play an important role in the adoption of OSH monitoring systems. The perception and awareness of needs in relation to OSH monitoring systems can significantly vary across companies and between employers and workers, depending on factors such as worker experience, immigration status, temporary employment, health conditions (people who are immunocompromised), age, pregnancy or lack of trade union representation. In such cases, new OSH monitoring systems might be adopted by companies to fulfil OSH obligations, improve OSH, or respond to market or worker pressure to modernise.
- **Hesitation and lack of buy-in among workers and their unions** may serve as barriers to the development of OSH monitoring systems. Limited **evidence and awareness** among employers and workers regarding the impact of monitoring systems on OSH may make it difficult to build trust.[31] Trust may also be eroded by fear of the **potentially hidden purpose of monitoring, which includes employee surveillance.**[32] Indeed, there are trade union concerns that the use of new monitoring systems could expose the workforce to **productivity pressures,** with potentially detrimental effects on health and wellbeing.[33] Further, concerns regarding **ethics, data protection, security and privacy** have also been voiced by workers and their representatives. These concerns may differ across Member States depending on legislative aspects and trade union strength. For example, in Italy, the privacy of workers is strictly protected by national legislation.[34] In northern European countries, unions

[29] EU-OSHA – European Agency for Safety and Health at Work, *Teleworking during the COVID-19 pandemic: risks and prevention strategies*, 2021. Available at: https://osha.europa.eu/en/publications/teleworking-during-covid-19-pandemic-risks-and-prevention-strategies

[30] See: European Parliament resolution of 21 January 2021 with recommendations to the Commission on the right to disconnect

[31] EU-OSHA – European Agency for Safety and Health at Work, *Occupational exoskeletons: wearable robotic devices and preventing work-related musculoskeletal disorders in the workplace of the future*, 2020. Available at: https://osha.europa.eu/en/publications/occupational-exoskeletons-wearable-robotic-devices-and-preventing-work-related

[32] Moore, P. V. (2017). *The quantified self in precarity: Work, technology and what counts*. Routledge.

[33] Ecorys interviews with stakeholders from trade unions, employer representatives and research organisations, conducted between November 2021 and February 2022.

[34] Tebano, L. (2017). Employees' privacy and employers' control between the Italian legal system and European sources. *Labour & Law Issues, 3*(2), C-1-C20. https://labourlaw.unibo.it/article/download/7576/7279/22871

often have a formal right to veto any measures that they consider not to be in the interest of their members.[35]

Optimising the uptake of new OSH monitoring systems – key takeaways for policy- and decision-makers

Initial research findings suggest that the uptake of new OSH monitoring systems is increasing slowly but that their use is still limited. This raises questions about the inhibiting factors influencing the adoption of such systems in workplaces. Experts[36] have called for further research to be carried out in order to enable a deeper understanding of where and how new OSH monitoring systems are developed, implemented and used. The aim is also to fill data gaps in order to provide information on which countries, sectors, companies and professions engage with these technologies.

In this context, the following key takeaways are offered with a view to optimising the uptake of new OSH monitoring systems.

Takeaway 1: Encourage effective communication of relevant research and data

It is often challenging for companies to obtain sufficient information to properly evaluate the costs, anticipated impacts and potential benefits of adopting new digital OSH monitoring systems.[37] This is due to the limited availability of research and concrete examples of the effectiveness of digital systems. While there may be more visible examples of these systems at specific events and conferences, the dissemination of data can be inadequate at times.

If better communication of available research and data is undertaken, this will enable employers to make informed decisions regarding the adoption of digital OSH monitoring systems in their organisation.

Effective communication also involves discussing the main advantages and disadvantages of digital OSH monitoring systems within the workplace. Research shows there is still some reluctance among workers and their representatives regarding the adoption of these systems. Encouraging employers to have open discussions about these systems with their employees could go a long way in dispelling these concerns.

Takeaway 2: Work towards the development of well-defined and evidence-based standardisation within the EU digital single market

As this research has shown, there are numerous challenges associated with standardisation in the adoption of new OSH monitoring systems. This is acting as a potential barrier. Additionally, standardisation is increasingly occurring on the global scale in areas such as information and communication technology (ICT), resulting in discrepancies with the standards established by 1025/2012 Regulation on European Standardisation.[38] In response, social partners argue that the EU should invest more in establishing standards for the EU digital single market.[39]

While it may be challenging to solve all the issues related to standardisation, efforts should be made to try to resolve complex situations whereby, for example, smart PPE is subject to new or additional layers of standardisation requirements.

Takeaway 3: Enable a wider discussion on privacy and the protection of data

The growing use of new digital technologies in the workplace has raised numerous questions about worker privacy and the risks inherent in new monitoring and surveillance techniques. Concerns about worker privacy, data protection and wider ethical issues such as the 'human in control' principle, constitute potential barriers to the adoption of these technologies. Scholars highlight the fact that workers are often aware of the

[35] Ecorys interviews with stakeholders from trade unions, employer representatives and research organisations, conducted between November 2021 and February 2022.
[36] Ecorys interviews conducted for this study, from November 2021 to February 2022.
[37] Ibid.
[38] See: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32012R1025&from=EN
[39] European Trade Union Confederation. (2016). *ETUC resolution on digitalisation: "Towards a fair digital work"*. https://www.etuc.org/en/document/etuc-resolution-digitalisation-towards-fair-digital-work

technological possibilities for improving OSH, at least regarding the improvement of their health and wellbeing.[40] However, some resistance may persist due to these concerns.

Open discussions at all levels, including EU level, national level and in individual companies, would help to clarify a range of issues relating to privacy, ethics and data protection. If employers understood and engaged with worker concerns in these areas and were able to offer reassurance, interventions could be designed to reduce resistance and motivate workers to use these systems, even though they may have to make some trade-offs in terms of privacy.[41]

Takeaway 4: Enable a more inclusive process, from the planning and design to the delivery and use of new OSH monitoring systems

Evidence suggests that OSH monitoring systems have the potential to meet the needs for workers with a range of different characteristics, including older workers, those with disabilities, and those with a migrant background. Exoskeletons, for example, which monitor stressors and vital signs, can support rather than replace workers, and can also create better access to work for disabled people.[42] However, while such technologies are promising, their implementation must ensure safe, ethical and human-oriented usage.

Establishing trust is key here, and this can be created by involving everyone more fully in the implementation of new OSH monitoring systems, from the planning and design phase to the actual implementation of systems at organisational level. In particular, if the social partners, including employer and employee representatives, are fully involved, they can effectively communicate issues from employers and workers, ensuring that their concerns are considered at all stages of implementation.

Takeaway 5: Ensure adequate support for SMEs

Research suggests that establishment size is a key influencing factor in the uptake of digital technologies at workplaces. Smaller companies appear to struggle with the adoption of new worker monitoring systems. Therefore, it is important to consider their specific needs at every level. There may be ways in which SMEs could form networks to share investment, resources and ideas, which may provide support. This could be encouraged by EU and national policy initiatives.

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[40] Yassaee, M., & Mettler, T. (2019). Digital occupational health systems: What do employees think about it? Information Systems *Frontiers*, *21*, 909-924. https://doi.org/10.1007/s10796-017-9795-6

[41] Ibid.

[42] EU-OSHA – European Agency for Safety and Health at Work, *Occupational exoskeletons: wearable robotic devices and preventing work-related musculoskeletal disorders in the workplace of the future*, 2020. Available at: https://osha.europa.eu/en/publications/occupational-exoskeletons-wearable-robotic-devices-and-preventing-work-related