SMART DIGITAL SYSTEMS FOR IMPROVING WORKERS' SAFETY AND HEALTH

SMART INSOLES FOR LONE WORKER PROTECTION

1 Introduction

Smart digital systems and technologies entering EU workplaces are reshaping work environments for workers and employers alike. Innovations in smart wearables, exoskeletons, artificial intelligence (AI), machine learning (ML), internet of things (IoT), virtual and augmented reality (VR and AR), among others, are giving new opportunities for preventing and responding to workplace risks.

As part of EU-OSHA's occupational safety and health (OSH) overview programme (2020-2023)[1], EU-OSHA has examined the challenges and opportunities of smart digital tools and monitoring systems for improving workers' safety and health. These systems, leverage digital technology to collect and analyse data in order to identify and assess risks, prevent and/or minimise harm and promote OSH.[2] EU-OSHA has categorised such systems into proactive (preventive) and reactive, albeit acknowledging the potential overlap between the two.[3] EU-OSHA further provided an overview of the risks and opportunities associated with these systems[4] and explored the workplace resources that could ensure their safe and healthy use.[5]

In order to investigate the practical implementation of smart digital tools and new OSH monitoring systems for improving workers' safety and health, EU-OSHA has developed a number of case studies. This set of case studies includes both cases of smart digital systems at the level of design/development and cases of companies implementing the systems. The case studies accordingly investigate aspects related to the design/development stage and to the implementation stage. OSH aspects including worker's involvement was considered in all case studies taking into account the type of case study. Further all case studies look at possible drivers, barriers and success factors for safe and effective implementation.

To develop these case studies, apart from desk research, a number of interviews with key informants were conducted, including workers' representatives, safety officers, employers and representatives of industry associations. In addition, at company level, up to five interviews were conducted with operators, data protection officers, health and safety engineers, managers, work councillors and technology officers. The interviews had a duration of 1-1.5 hours each and were performed in the participants' native language, if possible, or alternatively in English, an interview guide, while the results of the interviews were anonymised. The case studies referring to designers' results do not contain detailed information on workplace implementation, as there has been limited collection of information from companies in which the systems are installed.

In total 15 cases were identified, and preliminary information was collected for these through a questionnaire, hereafter, nine of them were further developed into case studies.

[1] For more information, see: osha.europa.eu (n.d.) Digitalisation of work. Available at: https://osha.europa.eu/en/themes/digitalisation-work

[2] EU-OSHA (2023). Smart digital monitoring systems for occupational safety and health: uses and challenges, https://osha.europa.eu/en/publications/smart-digital-monitoring-systems-occupational-safety-and-health-uses-and-challenges

[3] Ibid.

[4] Ibid.

[5] EU-OSHA (2023). Smart digital monitoring systems for occupational safety and health: workplace resources for design, implementation and use, https://osha.europa.eu/en/publications/smart-digital-monitoring-systems-occupational-safety-and-health-workplace-resources-design-implementation-and-use

2. Description of the smart digital system for OSH

1.1 General company description

This case study is on a French company that is using new technologies to improve occupational safety and health (OSH) for workers and companies. In 2019, after five years of research and development, the company launched the smart insoles for lone worker protection. The company's connected solutions turn safety shoes into smart personal protective equipment (PPE) that can be used in multiple sectors, particularly those including lone workers.

1.2 System description

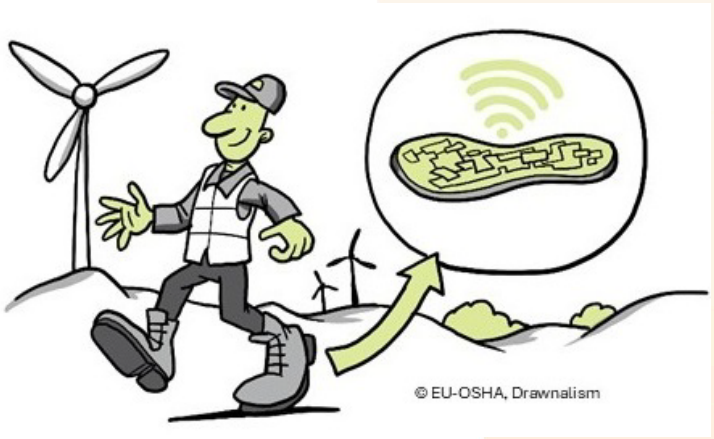
1.2.1 What is the system about?

Lone workers in high OSH risk sectors can be exposed to several risks such as falling (including from heights) or hostile behaviours or incidents, requiring evacuation from a worksite. In the EU, almost 600,000 accidents at work occurred in 2019 due to slipping, stumbling and falling, 520 of which were fatal.[6] The smart insoles are designed to protect workers from such risks without any need for further equipment. Indeed, the insoles, which provide hands-free protection, are worn in workers' safety shoes just as ordinary insoles are. The integrated sensor alerts the employer when a worker is in danger.

1.2.2 How does the system look?

The system consists of the insoles, fitted with an **integrated sensor/electronic module** using the same technology as a smartphone, and a **wireless charger**. The insoles are available in a range of sizes, from 36 EU to 52 EU. They are waterproof and can be used at temperatures of up to 50 °C. Moreover, the insoles' electronic module is shock, humidity and dust resistant (ATEX[7] version - designed to be safe in explosive atmospheres - will be available in 2024).

Figure 1: Cartoon-style representation of the system



1.2.3 How does the system work?

The insoles are designed to provide alerts in three cases of emergency:

1. Worker down detection; [8]
2. voluntary SOS; and
3. evacuation.

In the case of a fall, an **integrated sensor detects when the worker is in a non-conventional (horizontal) position. This triggers a pre-alarm which begins to make the insoles vibrate** (on and

[6] data.europa.eu (2023). Accidents at work by sex, age, severity, NACE Rev. 2 activity and material agent of deviation, https://data.europa.eu/data/datasets/pvupzm4u1ddq7awdxlei6w?locale=en

[7] See Directive 2014/34/EU, which covers equipment and protective systems intended for use in potentially explosive atmospheres: https://single-market-economy.ec.europa.eu/sectors/mechanical-engineering/equipment-potentially-explosive-atmospheres-atex_en

[8] System traditionally known as 'man down detection'

off). Should the worker not react after 30 seconds, the insole automatically sends an emergency geolocated alert to the employer.

The SOS alert can be used in instances where the worker feels unsafe or at risk of violence or aggression. The worker can discreetly alert their employer to the danger by tapping their right foot against their left foot three times.

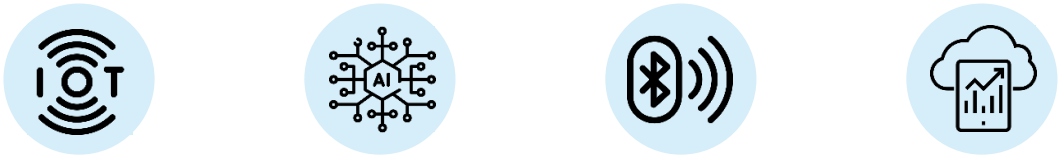
Finally, if an evacuation is necessary (as in the case of a fire), a safety manager can send an evacuation notice – causing long vibrations in the insoles – to facilitate the evacuation of a group or individual workers. The solution allows the employer and safety manager to follow the evacuation in real time to ensure all workers have left the site.

The smart insoles thus allow workers to send alerts to their manager as well as managers to send alerts to workers, providing a two-way system of communicating emergencies. Alert signals are sent to and processed by the product manufacturer's secure cloud platform, which immediately transfers the information alert to the safety manager or supervisor in charge through an app notification, SMS or email, along with the wearer's geolocation.

1.2.4 Technologies employed in the system

In terms of technologies, insoles include a sensor/electronic module that combines GPS (Global Positioning System), GSM (Global System for Mobile communication) and Bluetooth technology. All alerts are sent and managed through an application, which can be accessed by a supervisor from a smartphone or computer web browser. The application allows the supervisor access to numerous parameters: insole battery levels and charge indicators, site maps, status and position of indoor beacons, accident situation status and group.

Figure 2: Technologies employed by smart insoles



SIM card with 2G/4G M2M connectivity (IoT)	Cloud-based platform	Long-range Bluetooth	Cloud-based analytics
Transfers workers' data from the insole to the cloud.	Cloud-based software is used for tracking workers.	Covers areas where 2G/4G network is unavailable.	Sends app notifications, SMS or email to safety managers.

Additional equipment can be used to improve coverage. For example, the product manufacturer can use boost **positioning devices (beacons)** that can be used inside industrial buildings where satellite coverage may be more limited The beacons can provide the position of an alert on a building plan, including the specific floor in which the incident has occurred including high structures with different levels (chimneys, scaffolding, and so on). There are additional customisable functions provided by beacons as indicated below.

- Danger function: the smart insoles vibrate when workers enter a dangerous zone, such as a hazardous substance storage area, so that workers are alert to the increased risk. This function can also be fixed on a vehicle.
- Confidential function: the smart insoles do not communicate (i.e. provide any data) in certain delimited zones like changing rooms.

Finally, another piece of equipment which can be used with the insoles is a device that allows coverage in zones lacking a GSM network. The device relays alerts that are sent by the smart insoles to the cloud network through GSM, Wi-Fi or ethernet networks, with coverage of up to 200 m distance.

1.3 Examples of use

The product manufacturer's clients (implementing companies) are primarily from industries with high OSH risks: energy, construction, pharmacology and chemicals, and facility management. However, the company also has clients in sectors such as transportation of dangerous materials, logistics, food, gardening, security, cleaning companies and engineering services.

One key feature the product manufacturer identifies among its implementers, regardless of industry, is an existing strong approach to OSH, to which the smart insoles contribute. This highlights that while lone worker protection systems can help reduce risk, ultimately the implementing company's culture is the deciding factor in reducing and managing risk.

Figure 3: Applications of smart insoles across sectors

Construction	Pharmaceuticals and chemicals	Facility management	Energy

Health and safety managers are usually the ones engaging with the product manufacturer on behalf of a company, even if site managers and higher levels of management are involved in the implementation at later stages.

2 Drivers and barriers to the design and implementation of the system

2.1 Motivators and goals

The idea to bring digital technologies into footwear originated from within the shoe industry. The transition from shoes to insoles, followed by a shift towards the safety shoe market, was prompted by workers' need for better safety features in the most widely worn PPE. In this context, the system was established in 2013, shortly after conducting a feasibility study for a connected shoe designed initially to protect children. Subsequently, a second target emerged, with a focus on providing safety features for dependent individuals, and later during the research and development phase, the study transitioned to a model serving the OSH sector.

The system sought to solve serious issues in high OSH risk sectors including:

- the challenge of workers forgetting existing lone worker protection systems (i.e. PPE) at home;
- the need for communication equipment that could work indoors as well as outdoors, and which is able to cover no-signal areas; and
- the need to bring these solutions to industries exposed to explosive risks (ATEX).

The manufacturing/designing company was initially funded through personal resources and support from public institutions, and later supported by private investors in 2019. The module incorporates its experience with comfort and certification which was already accounted for in the design phase of the product. The foam comfort insoles are produced by a leading manufacturer of sports insoles.

2.2 Drivers

The company tackles various challenges in lone worker protection by integrating its alert system into safety shoes. This system offers a proactive risk management approach by **addressing the issues of forgetfulness, discomfort and the risk of damage associated with traditional devices**, offering **a discrete, efficient and ergonomic safety measure** for improved workplace safety. Standard lone worker protection systems are typically devices in the form of accessories which can be forgotten or momentarily put aside for practical reasons by workers, such as when they need to kneel

or lay on the ground. They can also be cumbersome and uncomfortable, as in some cases they must be worn close to the body for the entire workday. Safety shoes are the most commonly used safety equipment in high-risk professions. By integrating the alert system into them, the system makes use of technological advancements to improve the functionality of traditional safety equipment. Not only is workers' mobility unimpacted, but the risk of forgetting to put them on is eliminated. As the device is hidden and thus protected, it is less likely to be damaged and cause false alerts. Moreover, starting the device is as simple as walking: the integrated sensors in the insole are activated by movement. This allows for easy deployment by companies and users, therefore contributing to operational efficiency.

Another significant advantage is that the device operates **independently of smartphones**. This feature proves crucial in areas with connectivity challenges, and means workers are not required to carry their phones during tasks. It is worth noting that many blue-collar workers in relevant sectors do not receive company-issued phones.

Because the insole embedded software updates automatically during **overnight charging**, no further action is required on the part of the employer or the worker to ensure its seamless functioning. Moreover, in cases where the battery is malfunctioning or no longer charging, the product manufacturer alerts its clients.

Another key feature of the protection system is that it is highly **customisable, based on the implementing company's (clients) needs and the layout of the worksite**, including additional devices boosting positioning features or allowing coverage in all areas. Customisable features include not only the insole itself, which can be tailored to meet the **specific orthopaedic needs** of a worker, but also the data collected and monitored through the product manufacturer's application. Furthermore, users benefit from the flexibility to define the zones in which the alarm functionality operates, which increases their control over safety measures. This customisability is also important, given **data privacy** concerns. For example, the insole ensures confidentiality by activating the geolocation system **solely during alerts**, safeguarding workers' privacy rights. Moreover, while the data is processed on the product manufacturer's cloud platform (General Data Protection Regulation (GDPR) compliant), the ownership of the data remains entirely with the client.

Other key drivers of this system are indicated below.

- The wearable technology provides workers with the **peace of mind** of knowing that the employer can always be warned of any issues, or that the employer can alert them to issues they may not be aware of, even in the most isolated environments, adding to their sense of safety and wellbeing at work.
- The collected data that workers can access and review through the online platform can **empower** them to be more aware of and improve their safety practices.
- The detailed data collected by the device **facilitates the investigation of incidents** and contributes to the **improved assessment of risks.**

All the features mentioned above (summarised in Table 1) can serve as important drivers for the uptake and implementation of smart insoles in the workplace. As previously mentioned, effectively leveraging these drivers and maximising the potential of smart insoles for safety and health also relies heavily on the presence of a robust safety and health culture within the implementing organisation.

Table 1: Smart insole key (non-osh) benefits and features

Benefits	Features
Integrated into the most used PPE – low risk of forgetting the system.	Highly customisable.
Autonomous – turns on by itself.	Rapid alert time, reducing rescue operation times.
Confidentiality – location data are only shared in case of alerts.	Two-way alert mechanism between employer and worker.

Benefits	Features
Suitable for mobile or static lone workers.	Durability (waterproof, humidity, shock and dust resistant).
Ergonomic – comfort is prioritised in the design.	Automatic updating of software.

2.3 Barriers

Safety footwear is a regulated industry. The product faced some challenges in the development phase when gaining **compliance with the relevant standards**. The developer worked closely with safety shoemakers, laboratories and PPE distributors to understand the legislative constraints and standards with which the insoles would have to comply. As noted previously, the insoles are produced by an existing insole producer, who is already certified and familiar with the legislative norms, which facilitated the production process. Still the new product needed to be certified again.

Another challenge was the **high cost of developing** the product. The company notes that the availability of both public and private financing was fundamental to moving the technology forward. Beyond the regulatory barriers, the **long research and development (R&D)** period was also a challenge that added to costs. Overcoming the challenge of developing efficient passive antennas that operate within a body area network, coupled with electronic systems in challenging environments and creating a services platform compliant with industrial regulations constituted a five-year endeavour. Developing will be a continuous activity, for example currently an *ATEX* (equipment for potentially explosive atmospheres) version of the smart insole, a *permit-to-work* system and a *vehicle-pedestrian* coactivity system to reduce potential accidents in logistic and construction sites.

Adoption hesitance had been one of the common barriers in the initial integration of the smart insole for workplace safety. Workers often had **privacy concerns**. They feared that the system would be used as a surveillance mechanism by their **employers to monitor their location and to assess their performance**. To overcome these concerns, organisational culture played an important factor. In workplaces where the leadership communicated clearly and transparently about the tool's purpose, functionality, and data handling, workers were more open to accepting the system.

Equally, it should be noted that **compliance with data privacy and data protection regulation can be complex**, which may act as a deterrent for some employers to use a system that collects such data.

3 OSH impact

3.1 Opportunities

The implementation of smart insoles for lone workers offers a number of opportunities for workers and employers alike.

The smart insole system primarily operates as a **reactive** OSH monitoring system. The system allows employers to be **alerted to risks that lone workers may face in real time**. In cases where a fall occurs, the worker does not need to activate the alert themselves. This is an important feature in hazardous environments where a person may lose consciousness, for example, and be unable to signal for help or share their location. The GPS system means that **employers do not have to take additional time trying to locate themselves** and can focus on rescue operations within seconds.

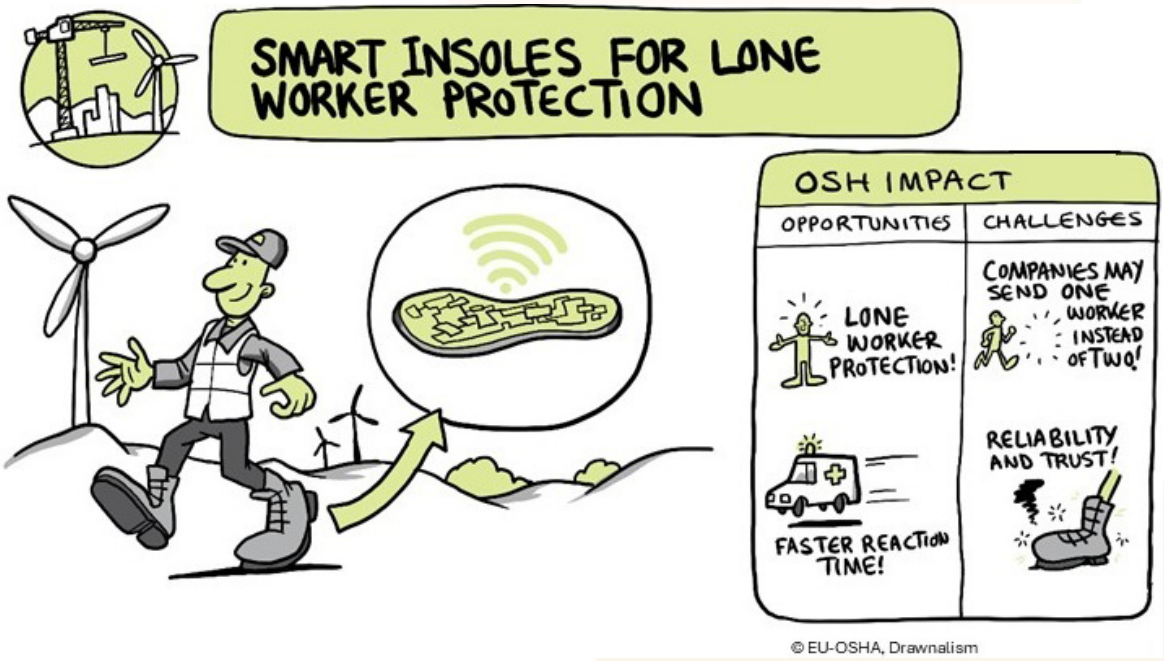
Moreover, workers can proactively **signal an alarm to employers through the SOS function**. Crucially, they can do this in a discreet manner, which may be useful in situations where they may be at risk of aggression. In those instances, they can send a distress signal without alerting their attacker.

The two-way communication that the smart insoles provide means that **employers can alert all workers to an evacuation** simultaneously, which may significantly reduce evacuation time. Location information allows employers to monitor the progress of the evacuation and **identify workers who may be at greater risk than others**. Thus, the system allows users to not only signal and locate emergencies, but also to assist in responding to them. This is an important tool that can help companies react to risks and possibly save lives.

These reactive features also allow the system to contribute to the proactive management of OSH risks. With the automatic storage of information in the system's cloud, employers can **engage in more accurate accident investigation and reporting**. Ultimately, these findings can serve as lessons and contribute to improved **identification and assessment of risks to prevent harm early.**

Opportunities for prevention go beyond this however because the smart insoles can also signal to workers when they are entering a high-risk zone. This allows them to be **more aware of risk**. Further opportunities for OSH could result from addressing specific orthopaedic needs.

Figure 4: Smart insoles for lone worker protection: Challenges and opportunities for OSH



3.2 Challenges

Smart insoles for lone worker protection offer many opportunities. Nevertheless, there may be some potential challenges to using the system.

While the probability is very low, it is essential to acknowledge that every technology has the potential to **malfunction**. Batteries may lose their efficiency over time, and in certain conditions they may even overheat or explode.[9] Moreover, electronic parts face the risk of damage, for instance, through accidental water damage.

Moreover, like all wearables, the tool still relies on the proactivity of **workers to ensure it fulfils its function.** While the integration of the insoles into workers' safety shoes limits the risk of forgetting to put them on, the smart insole cannot perform any of its functions if it is not charged regularly (approximately every two days).

Additionally, while standard safety procedures often dictate the deployment of two workers in remote or hazardous areas, **the potential protection offered by the smart insole system may be viewed by some employers as a substitute for human presence**, thereby creating more risks for workers. As highlighted in the *hierarchy of controls*[10]*,* personal control measures, such as smart PPE, should not replace collective protective measures that safeguard all workers at all times, rather than just one individual. It is important for personal control measures such as the smart insoles for lone workers to be complementary to collective protective measures.

Lastly, as noted previously, **the initial hesitance** to adopt the system, does indicate the **potential for negative psychosocial impacts on workers** when smart monitoring is perceived as a performance

[9] 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-intelligentprotection-future/view

[10] EU-OSHA – European Agency for Safety and Health at Work, *Hierarchy of prevention and control measures,* 2012. Available at: https://oshwiki.osha.europa.eu/en/themes/hierarchy-prevention-and-control-measures

evaluation tool and not exclusively as a safety tool. To manage this risk, it is vital that employers wishing to integrate smart insoles into their OSH practice consult their workers prior to implementation and provide transparency on how collected data will be used and stored in line with data privacy regulations. The system developer involves the workers (end-users) as soon as the testing begins, and encourages the implementing employers' (OSH-) management to directly involve workers in the implementation of its system to reduce the concerns and to inform them about personal data protection and procedures followed. Data privacy and confidentiality are discussed with workers and implementation of the start.

Addressing these concerns is an important prerequisite for the safe and healthy use of these systems in the workplace.

4 Takeaways for development and implementation

Regarding the development of smart insoles for lone workers, product manufacturers/ developers should:

- make certain features of their products, such as geolocation data, available only in specific circumstances, for privacy reasons, such as when an alert is triggered, and make sure the employers discuss this with workers from the beginning;
- offer test phases (in collaboration with implementing companies), where workers can check the monitoring system and ask questions. For example, through the test phase, the French manufacturer shares the application's data (initially dedicated to supervision) with the workers, so they can see which data their employers can assess. This transparency allows the product manufacturer to address workers' main concerns that might hinder implementation;
- provide online video tutorials, user guides and a frequently asked questions section on their website and organise audio and video meetings as well as onsite visits to support implementation, where necessary.
- design products that are easy to use For example, smart insoles can support workers forgetting to wear them.

Regarding the implementation of smart insoles for lone workers, employers should:

- directly involve workers in the implementation of their systems, to reduce concerns around privacy and provide information on data protection and data privacy procedures followed;
- develop a strong OSH management culture. The case study found that workers' receptiveness to the protective system depends largely on their own awareness of safety and risk, as well as the OSH management culture in their company. In certain cases, for example, the workers or a trade union requested the use of the smart insoles from their employer.
- when selecting the system, it is important to consider workers' comfort, including meeting specific orthopaedic needs, as well as exploring various customisation options that could assist in addressing privacy concerns, such as enabling geolocation only in case of emergency.

List of abbreviations

AI	Artificial intelligence
AR	Augmented reality
ATEX	Refers to the ATEX Directive 2014/34/EU, covering equipment and protective systems intended for use in potentially explosive atmospheres
FAQ	Frequently asked questions
GDPR	General Data Protection Regulation
GPS	Global Positioning System
IoT	Internet of things

ML	Machine learning
OSH	Occupational safety and health
PPE	Personal protective equipment
R & D	Research and development
VR	Virtual reality

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