SMART DIGITAL SYSTEMS FOR IMPROVING WORKERS' SAFETY AND HEALTH

SMART ARMBAND FOR REAL-TIME DATA ANALYSIS FOR HEALTH & SAFETY

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 new OSH monitoring system

2.1 General company description (developer)

The company is a micro-enterprise established in 2016 in the United States, providing data, analytics and software as a service. It implements **wearable technology that collects real-time environmental and motion data,** among other things. With the new smart systems, the company aims at improving workers' health, safety and productivity while mitigating workplace risks and reducing worker compensation claims.

2.2 System description

The device is worn in a holster attached to a band on the arm of a worker and monitors their working environment, such as **heat, lighting and noise levels**. The device also tracks workers' **repetitive movements** and the **physical effort** that they put into a task.

When workers start their work, they take the device randomly assigned to them from the base station on a wall. The IoT-enabled sensors on the device gather real-time data on ever-changing environmental conditions and workers' potentially hazardous motions, proximity and location.

By monitoring environmental conditions, the wearables identify risks at the workplace such as excessive heat, inadequate lighting or noise-induced hearing injuries. The device also captures the motions of a worker which can aid in identifying common causes of injuries such as slips, trips and falls. Similarly, the system allows for the identification of the locations in a facility that carry higher risks than others.

The wearable technology also facilitates **near-miss reporting** by allowing the workers to click on the device and leave a **voice memo** about the workplace hazards they observe. Near-miss reporting covers the risky situations where no damage or injuries were observed, but where they easily could have occurred. Workers often need time for paperwork to report such cases.

Hence, traditional near-miss reporting is relatively uncommon in the workplace. The voice memo feature makes the near-miss reporting process easier.

Data gathered by the wearable are sent to a **cloud-based software system where they are analysed and filtered into trends and patterns.** The trend and pattern analysis relies on an array of sensors on **different devices worn over time**, creating a matrix on various individuals rather than collecting data from a single device.

Managers and safety professionals can implement control measures based on data that show potential hazards, thereby preventing incidents. Attention to data can facilitate process improvements and detect environmental and ergonomic threats.

This technology aims to mitigate workplace hazards and reduce the frequency and severity of workers' compensation claims, resulting in enhanced administration compliance. It is used to identify risks in various sectors including light and heavy manufacturing, construction, food packaging and agriculture.

2.2.1 How does the device look?

The wearable device attaches to a holster on an **adjustable armband worn on the worker's upper arm** over their clothing. Armbands are not shared, and replacements are readily accessible as needed. The device can be returned to a kiosk at the end of a shift. It is recharged and promptly made available for the next worker, if necessary. A **device is randomly assigned to workers each day.** Hence, a device collects long-term data about the work environment instead of tracking a specific worker.

The wall-mounted base station kiosk accommodates up to 20 wearable devices. Working anywhere with a functioning power connection, the kiosk is a central hub for charging, provisioning and facilitating seamless internet communication with the cloud platform. The workers can use the keypad to enter their unique identifier to pair the device to themselves until the end of the shift. The kiosk offers both wired and wireless connectivity options for added flexibility.

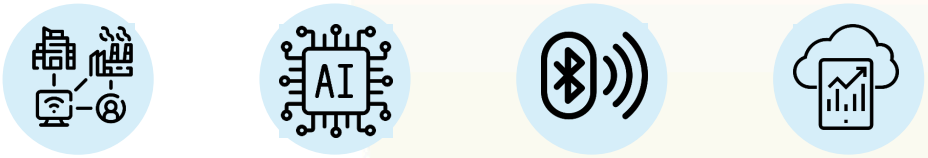
2.2.2 How does the system work?

The types of real-time environmental-related data gathered by the wearable include light, air quality, and pressure noise, humidity, and temperature. Additionally, as stated above, the wearable allows

workers to record near-miss voice memo reports, 'good catches', and observations from the front lines with the touch of a button. For instance, when a worker almost falls at the threshold of a door and sends a voice memo about that, the product **might reveal that many other workers have had similar problems at the same location.**

As soon as a worker returns the wearable to the kiosk at the end of a shift the data collected are immediately sent to the cloud analytics, with the help of the Wi-Fi network. Then, the system displays data analytics, **uses AI and ML to discern trends, and generates alerts and recommendations**. These reports and leading indicator data are sent to safety leaders so that they can take measures to prevent accidents before they happen**.**

Figure 1: OSH monitoring system's use of technologies



IoT	AI and ML	Bluetooth	Cloud-based analytics
IoT-enabled sensors on the wearable transfer data to cloud-based software.	AI-backed ML models can accurately label trends and patterns in real time.	Bluetooth used alongside Wi-Fi is being further developed to transfer data from the kiosks during off-site work.	The software is used for the collection and analysis of the data to implement preventive measures.

2.2.3 Examples of use

Real-time data analysis for health and safety is important in various industrial settings, especially those that include high-risk or hazardous environments such as construction sites, logistics and warehousing facilities, trucking operations, high-volume operations, and foundries—specifically steel foundries. The system is used in various sectors including heavy and light manufacturing, food packaging and processing, and agriculture. For instance, numerous cattle ranches use the solution to address safety concerns related to strain, exertion and physical movement for cowboys and livestock workers. In construction sites, issues that were addressed include high-heat notifications from the workers on decking metal and high-noise levels that are unexpectedly affecting more workers.

Steel foundries are known for being potentially dangerous working environments. In a steel foundry, a shift supervisor was notified of a hazardous motion by the wearable device when a worker tripped on a new, small ergonomic mat. Following the incident, larger mats were considered more appropriate, and replacements were made.

In the commercial textile sector, the wearable identified a high-force unclassified push-and-pull motion from an ageing worker. Then, the safety manager and worker discovered that the heavy cart had damaged casters. The cart was sent for maintenance. On another occasion, the safety leader compared the data from the workers across four different worksites and found out that workers at one location were doing their tasks with 750% more physical effort than at the other locations.

In a company that operates in food packaging, a worker promptly used a voice memo to report the highly slippery surface in their entire department. Upon investigation, the safety manager discovered that an incorrect type of paint had been applied to the floor. The maintenance team had inadvertently used glossy paint without incorporating any grit, creating a significant slip, trip, and fall risk. By addressing this issue, the company potentially avoided probable injuries.

3 System implementation: Drivers and barriers

3.1 Motivators and goals

The founders of the company developing the system saw the need for continuous monitoring at industrial facilities so preventive measures could be put in place, unlike the traditional approach in which safety professionals can only take action post-incident. This was the rationale behind the idea of collecting information about possible risks in the working environment as well as near misses.

A suitable design for smooth real-time data analysis was among the main concerns. The executives of the system developer highlight that among the many proposed solutions for sensor placement, including the front, back, helmet, upper arm, or belt of the worker, they decided that the upper arm was the most convenient placement for capturing environmental data. Hence, the wearable was designed as a holster on an armband.

The main product was launched at the onset of the global pandemic in 2020. Despite the lockdown, the solution could expand through pilot programmes, proof of concepts, and beta deployments in select industrial facilities. Currently, the solution provided by the company has extended to clients in the United States, Europe, Central and South America, South Africa and Asia.

Moreover, the system developer has been **partnering with insurance companies** since its establishment to gather data about industrial risk so that the insurers can work with their policyholders. Insurer partners of the company involve their policyholders in the process so that the system can be introduced to both parties through anonymised sharing of aggregated, environmental and incidents' data. However, it should be fundamental that both the developer and the employer should ensure that no personal data will be shared or used for any other purpose. The goal of this use of the OSH system is to help transition to a predict-and-prevent model to mitigate risk at the industrial level.

3.2 Drivers

An important driver for the system is **automated record-keeping** and **enhanced reporting**. **Well-organised documentation** is an important responsibility for safety professionals to deal with regulatory bodies and national OSH authorities. In the case of an audit, the inspector may question how the operation can be considered safe if there is no proper record-keeping or documentation of incidents, including near misses and injuries.

The system ensures **proactive risk management** by identifying potential hazards before they escalate into serious incidents. This proactive approach allows for timely interventions, significantly reducing workplace accidents. Timely and **accurate hazard detection** ensures that potential risks are identified and addressed promptly. The wearable armband's **ergonomic monitoring** of the work environment and repetitive motions allow for timely interventions to improve **worker health and wellbeing**.

The system facilitates **worker empowerment** in various ways. Although the armband does not provide haptic feedback to workers, the data collected informs workers about their safety practices regarding where they put more physical effort and gives them the chance to report near misses and potential problems. Hence, the system encourages **personal-safety awareness** and proactive behaviour. Similarly, **involving workers in safety practices through technology can increase their engagement** and commitment to a safe workplace.

Regarding **incident investigation** as another driver, the system provides detailed data that can be invaluable during investigations of incidents or near misses, ensuring a thorough understanding of the events leading up to an incident.

User feedback plays a crucial role in guiding ongoing product developments and increasing the pace of these developments. For example, the product was originally intended for workplaces where workers come to the facility and work from there. However, due to the needs of various sectors and companies, a recent development is that workers can check out the wearable on a smartphone app and declare that they will be working remotely or in the field. Also, for safety professionals who use the dashboard, their

feedback has been considered to have an intuitive and easy to use dashboard. Moreover, one-on-one support is provided, where safety professionals can ask questions.

To have the workers familiarised with the technology, for smooth adaption it helps if **leadership wears it.** When safety professionals and other leadership wear the technology, it sends the message that they won't ask workers to do something they aren't willing to do themselves.

Implementing real-time data analysis for health and safety can address gaps in the OSH management system. By integrating this technology into their OSH systems, organisations can improve their OSH management processes, eventually contributing to a more effective safety framework. Wearables can also provide **aggregated, environmental and incidents' data to insurance carriers**. Data from workplace wearables create remediation steps to help streamline worksite-risk reduction and allow carriers to generate tailored advice for policies and justify premiums more efficiently. IoT capabilities further enhance this picture, with the ability to alert safety managers to potential risks or even take automated steps to help mitigate risks based on identified trends. Armed with this more complete picture of workplace risk, thanks to more accurate and precise trend data, insurance carriers can target, select and price risk more precisely for policyholders and accelerate time-to-value on policies. The individualised view of risk allows safety experts to accurately prescribe remediation steps specific to worker risks and better measure remediation efficacy.

Operational efficiency is another driver since addressing workplace-related issues that lead to physical strain results in **effective resource allocation** and **reduced downtime** as the pieces of equipment and workplace situations carrying risks would be replaced before any incident.

3.3 Barriers

Overcoming **worker privacy concerns** is an issue that could potentially hinder implementation. Workers may feel uncomfortable with continuous monitoring, leading to concerns about **privacy and surveillance**, hence, having clear policies regarding **data ownership**, collection and access is of paramount importance for organisations.

System developers mentioned that they see value in keeping the data for as long as possible because it provides insights into safety in the long run. Hence, the company does not have a specific data retention policy other than retaining the data indefinitely. However, if an end user explicitly requests their data to be deleted, the employer and the system developer are obliged to comply with that request and provide **a certificate of destruction.**

Moreover, there is a self-service feature on the app, where a file can be downloaded that shows everything known about a worker, including every voice memo they've left, their name, phone number, email address, as a **right to know what private information** is collected. In any case, as mentioned earlier, both the developer and the employer should ensure that no personal data are shared or used for any other purpose.

Implementing the system for real-time data analysis for health and safety also presents **legal barriers**. Compliance with stringent **data privacy laws** such as GDPR can be challenging, especially regarding the collection and use of personal data.

Workers' data-related concerns can be a barrier for the system if not taking into consideration in the development and implementation.

Moreover, it is important to note that the solution is not meant to be an emergency response system when someone is in distress and requires immediate assistance. Since taking responsibility for emergency site management carries significant liabilities, the system is rather **focused on proactive reporting to solve potential problems before they result in injuries**.

Regarding technical challenges, ensuring the wearables are robust, durable and reliable in various working conditions is essential. Additionally, **data management** poses another challenge, as analysing data on cloud-based software can be complex and resource intensive.

Although the system might not require substantial investment compared to many other OSH systems, implementing wearable systems still necessitates **dedicated investment** in purchasing the devices, deploying the necessary infrastructure and setting up the cloud-based analytics platform. Beyond the initial costs, **ongoing expenses** such as regular software updates, device calibration and battery replacements add to the financial burden.

Workers may be hesitant to adopt wearable technology, fearing it might be intrusive or burdensome. Overcoming this resistance requires **targeted training programmes** to ensure proper use and maximise the system's benefits. Moreover, workers need to understand how the technology enhances their safety and wellbeing to gain full support and cooperation.

The collection and transmission of data through devices introduces **cybersecurity** risks, including potential breaches that could expose confidential information. Data security requires robust encryption, secure data storage and strict access controls, which can add complexity and cost to the system.

Successfully implementing wearable systems requires strong **leadership support** to drive adoption and ensure effective use across the organisation. **Change management** is critical, as the introduction of new technology might require significant attention from the end user's side (employer and workers). Leaders must emphasise the system's benefits, address privacy-related concerns and provide the necessary resources to facilitate a smooth transition.

4 OSH impact

4.1 Opportunities

A significant opportunity that the device brings is **hazard detection**. Alongside detecting risks in the work environment, the system allows certain modifications to alleviate physical strain by identifying the locations and actions contributing to the physical strain of specific workers. For instance, the data can reveal whether a worker exerts more effort than another colleague due to their shorter stature. By raising their workstation by a few inches, the problem can be addressed. Hence, the system also **improves safety measures** by enabling quick action to mitigate risks before they result in injury or contribute to longer-term health problems.

Aggregated data from the wearable device offers a detailed and holistic view of workplace safety by collecting real-time information on environmental conditions, worker motions and near-miss incidents. This data enables safety professionals and managers to make **well-informed decisions** by identifying potential hazards and taking actions to mitigate risks. Moreover, identifying trends can inform longer-term OSH strategies.

Identifying and correcting hazardous motions can also reduce repetitive strain injuries, **improving ergonomics**. Hence, the system also prevents musculoskeletal disorders and reduces strain and exertion-related injuries. Data-driven insights can lead to better workplace design and ergonomic interventions.

From an OSH point of view, the easy memo recording of near misses that the system offers **encourages reporting processes** and provides valuable data for analysis. This also comes with **continuous improvement of safety protocols** as the data informs overall OSH management.

Proximity and location tracking is another opportunity. The Bluetooth technology on the wearable device enables it to detect the proximity between one worker and another wearing an armband. The technology proves beneficial for many applications where the proximity to others or equipment is important. Furthermore, the system displays worker density mapping that enables safety leaders to view the density of the worker population by facility location or site area over time. This intelligence can help safety managers determine areas that need additional safeguards to ensure social distancing or further cleaning and sanitation measures. As a company-issued personal protective equipment (PPE),

the wearable is also useful for **managing COVID-19**. Through the unique identifier system without identifiable information, that was mentioned above, the wearable can detect with whom a worker has been in close contact. An on-demand report is available to leadership if contact tracing is needed in a risky scenario.

The data collected by the wearables can be used in **training programmes** to demonstrate potential hazards and safety practices. By incorporating examples and trends identified from the data, training can be more relevant and effective, helping workers understand and avoid common hazards in their specific work environment.

Automated data collection ensures that all safety-related incidents, including near misses and hazardous conditions, are accurately documented. This **accuracy in record keeping** is crucial for meeting **regulatory compliance** with OSH standards. Moreover, the comprehensive and organised data provided by the system **simplifies the audit process**, as safety inspectors can easily access and review records. This streamlined process not only saves time but also enhances the company's ability to demonstrate its commitment to maintaining a safe and compliant work environment.

The table below outlines the key OSH opportunities of the system.

Table 1: Key OSH opportunities of the system

Key OSH opportunities
▪ Hazard detection and improved safety measures.
▪ Well-informed decision-making.
▪ Improved ergonomics.
▪ Reporting process encouragement and continuous improvement of safety protocols.
▪ Data privacy policy.
▪ Proximity and location tracking for enhanced cleaning and sanitation measures, such as COVID-19 risks.
▪ Training enhancement.
▪ Regulatory compliance with accurate record-keeping and easier audits.

4.2 Challenges

One of the biggest challenges underlined by a key interviewee representing the case company was addressing **workers' concerns about privacy**. Workers might assume that their biometric data is being collected, continuously tracked or their productivity is being monitored. Alongside the risk of **surveillance**, the workers might also fear that their **data is accessed or used improperly** or by unauthorised personnel. In addition, the fear that data referring to proximity between workers are used for other purposes could affect social interaction too. Therefore, employers should ensure the workers' trust in the technology through effective communication and the clear provision of information regarding the system's use, as well as the precautions taken for data security. This could be in the form of written commitment from the management to data protection and involvement of workers representatives in proper system use.

However, a core aspect of the system that tackles data-related concerns is the **data privacy policy** embedded in it. The wearable does not collect any personally identifiable information, biometrics, or any other type of data covered by the US privacy rule HIPAA (Health Insurance Portability and Accountability Act (HIPAA). Workers are not continuously tracked; the design of the system does not allow detection of a worker's location at a specific moment in time. The wearables on the armband emit unique identifiers in the form of radio frequency signals. The wearables listen for other signals in the

vicinity, and when two wearables detect each other's signals, the information is sent to the cloud. The cloud then associates the unique identifiers with the wearables' respective individuals. However, the wearables themselves do not contain any identifiable information. Hence, the technology is not focused on an individual worker but on **the experiences and exposures in the work environment**. For instance, the location is identified when an indicator has exceeded the thresholds or when snapshots of environmental conditions are taken.

Another challenge is **data security**. Wearable devices and their data can be targets for **cyberattacks**, risking data breaches. Hence, organisations must have solid data protection policies and measures. Ensuring the accuracy and reliability of the collected data is crucial for effective decision-making.

Another potential OSH related challenge brought on by the wearables is **false alarms** and **interruption of workflow**. Frequent false alarms may lead to workers becoming desensitised to alerts, reducing the system's effectiveness. Unnecessary alerts can disrupt the workflow and reduce productivity. However, for this particular system, the company came up with a solution to address such a potential challenge. No auditory, visual or haptic feedback is delivered to the worker, which could interrupt work or cause distraction.

Continuous connectivity is essential for real-time data analysis. The variability of the necessary infrastructure for smooth data collection, such as the lack of a stable Wi-Fi connection, can hinder data collection. There might be delays between a worker's warning of a workplace-related danger and a safety professional seeing the data. Several hours might be too late to prevent injuries or address risks. Hence, employers should ensure continuous connectivity, which could be especially challenging in an industrial environment. Connectivity issues might lead to **device malfunction**, wearable failure or incorrect data provision due to technical issues, leading to potential safety risks. Limited **battery life** can also affect the continuous monitoring capabilities of the wearables.

Moreover, in some sectors like food processing, workers have to wear protective clothing that they throw away at the end of the workday. The wearable can still collect the necessary data. However, the piece of clothing might lead to minor inconveniences by creating a barrier between the wearable and the outside world.

Some **workers might resist** wearing the wearable devices or fail to use them correctly, leading to gaps in data collection, potentially undermining the system's effectiveness. This resistance can stem from discomfort with the technology or a lack of understanding of its benefits. For example, the fear that the shared wearable could not be disinfected well.

Information overload is another potential challenge for safety professionals. The vast amounts of data generated by wearable devices can be overwhelming, making it difficult to manage and analyse effectively. Using this data to extract meaningful insights requires advanced analytical tools and a well-structured data management strategy. Furthermore, identifying **which data points** are most **relevant and actionable** for improving workplace safety can be challenging. Without clear guidelines and robust data-filtering processes, there is a risk of focusing on less important information, potentially overlooking critical safety issues.

There is also the potential challenge of a **false feeling of protection.** The workers may feel protected and take greater risks. However, this system is not meant for an emergency situation. This aspect of the system should be made clear to end users in training. In general, effective use of the system requires **comprehensive training** for both workers and managers, which demands time, effort and additional resources. Without proper training, the system's benefits and limitations may not be understood.

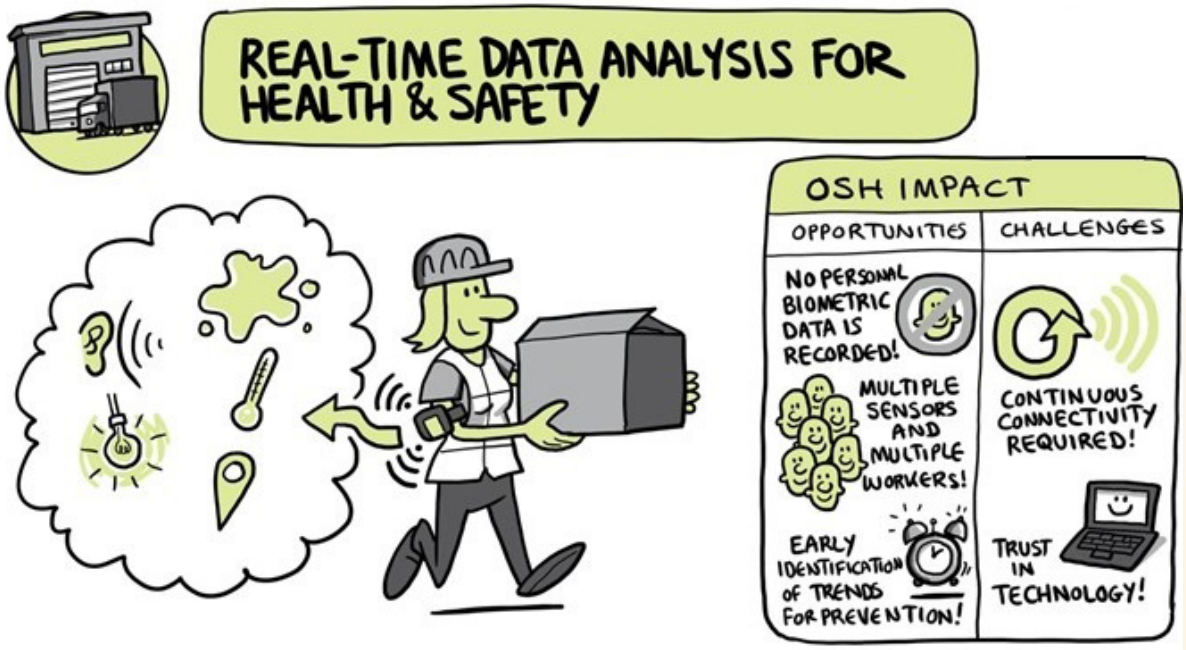
Table 2: Key OSH challenges of the system

Key OSH challenges
▪ Privacy concerns, worker surveillance and misuse of data.
▪ Data security and data integrity.
▪ False alarms and interruption of workflow.

Key OSH challenges
▪ Connectivity issues, device malfunction and limited battery life.
▪ Worker resistance and misuse of the system.
▪ Information overload and relevant data identification.
▪ False feeling of protection.
▪ Training needs.

A cartoon-style representation of the system, including some of the challenges and opportunities for OSH is presented in Figure 2.

Figure 2: Real-time data analysis for HSE: Opportunities and challenges for OSH



5 Takeaways for development and implementation

This section outlines the primary insights for developing and safely implementing a system based on real-time data analysis for health and safety, in this case, through wearable technology. Many of these insights are cross-cutting, as they apply to multiple cases analysed within EU-OSHA's research.

Takeaways for the development of real-time data analysis for health and safety. Product manufacturers should:

- maintain a privacy-centric design that addresses and alleviates worker privacy concerns;
- ensure that the system is in line with data privacy regulations;
- ensure that the system is used only for its intended use;
- establish clear data retention policies in line with the needs;
- establish clear data deletion policies in line with workers' requests
- streamline documentation and support safety professionals for regulatory compliance;
- engage the users/workers in the development stage (address use needs, etc.).

Takeaways for the safe and healthy implementation of real-time data analysis for health and safety. Employers should:

- act on the data insights to foster a proactive safety culture in the workplace, effectively offering support (training and coaching) to at-risk workers;
- comply with regulation regarding data privacy;
- use the system appropriately to promote OSH, making sure that workers do not take greater risks;
- acknowledge that the main responsibility to ensure safety in the workplace falls on employers, and it cannot be substituted by system indicators;
- recognise that the system is not intended for emergency response when a worker requires immediate assistance;
- clarify who owns the collected data and how it will be used and communicate the data collection policies clearly. These steps are crucial to ensure transparency and worker trust;
- involve workers in the decision-making process and address their concerns, which can also lead to higher acceptance;
- take precautions against potential system malfunctions.

List of abbreviations

AI	Artificial intelligence
AR	Augmented reality
GDPR	General Data Protection Regulation
HIPAA	Health Insurance Portability and Accountability Act
IoT	Internet of things
ML	Machine learning
OSH	Occupational safety and health
PPE	Personal protective equipment
SaaS	Software as a service
SME	Small- and medium-sized enterprises
VR	Virtual reality

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