SMART DIGITAL SYSTEMS FOR IMPROVING WORKERS' SAFETY AND HEALTH

PREVENTING HAND-ARM VIBRATION SYNDROME (HAVS)

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

2.1 General company description (designer)

The designer of the new smart digital system[6] in this case study is a United Kingdom (UK)-based SME founded in 2021 that is active in the field of occupational health and safety risk prevention. It employs approximately 40 workers, broadly distributed across three departments: product engineering, operations support, and sales and marketing. The company provides smart digital solutions that prevent HAVS (hand-arm vibration syndrome) through different smart digital systems employing an array of technologies. Their main system, as discussed in this case study, provides a fully automated exposure management support system used by over 140,000 workers in the UK.

2.2 System description

2.2.1 What is the system about?

The smart digital system is a **wristwatch that detects workers' exposure to hand-arm vibration (HAV) in real time**. The wristwatch can prevent HAVS by detecting when exposure levels become excessive. According to a study conducted by EU-OSHA, one in three European workers is exposed to vibrations at work.[7] The study also found that the prevalence of HAVS varies widely across different sectors, with the highest prevalence in construction, mining and manufacturing. Therefore, smart monitoring of HAV holds promise for improving the safety and health of a significant share of the workforce, particularly those in blue-collar occupations.

Tool exposure point (TEP) assessment is based on a static vibration magnitude programmed into a tool tag and the duration of tool usage. This is the **standard measure**.

Sensed exposure point (SEP) assessment is based on a real-time determination of vibration magnitude during all use of the tool, which if assessed to be representative, will comply with the regulations and health, safety and environment (HSE) guidance. Rather than simply taking the typical measure as set by the standards, it reflects **real use by a person**.

The company developed the first version of the smart digital system in 2008, to gather data on individual users' exposure to vibration.

In 2014, the company automated the data collection and analysis of HAV exposure: it used mobile phone networks to transmit data and released a web-based portal to analyse the data. Two years later, in 2016, it made its monitoring technology wearable by developing a wristwatch. This watch collects, calculates and transmits health, safety and environment (HSE) data on HAV risk exposure using tool exposure points (TEPs) and sensed exposure points (SEPs). This is possible through a sophisticated **sensor and software technology**. An independent assessment by the Institute of Occupational Medicine (IOM) indicated that traditional assessment methods such as the TEP can often fail in capturing exposure. Unlike TEP assessments, SEP assessments pick up previously unidentified exposure risks.

2.2.2 How does the system look?

The wristwatch provides workers with real-time information on their exposure by calculating and displaying their exposure risk assessment. It also shows the initials of the wearers and the current tool in use, for example, the 'drill'. The wristwatch displays exposure thresholds through a black circle appearing in colour segments (green, yellow and red), which alert the wearer of incremental increases in exposure. In particular, **sound and vibration alerts** inform the worker of potential risks, with these alerts increasing in line with vibration levels. To estimate the HAV exposure risk, the wristwatch relies on the British HSE exposure point system.[8]

[6] The terms 'OSH monitoring system', 'smart monitoring system' and 'smart digital system' are used interchangeably in this report.
[7] EU-OSHA – European Agency for Safety and Health at Work, *Report - Workplace exposure to vibration in Europe: an expert review*, 2008. Available at: https://osha.europa.eu/en/publications/report-workplace-exposure-vibration-europe-expert-review
[8] For more information, see: Health and Safety Executive https://www.hse.gov.uk/. (n.d.). *Exposure points system and ready-reckoner*. https://www.hse.gov.uk/vibration/hav/readyreckoner.htm

2.2.3 How does the system work?

After collecting the wristwatch, workers simply attach it to the tag of the tools they are using during their shift. At the end of their shift, they return it to a docking station, where it charges and uploads the data to the product manufacturer's analytics platform. Through this platform, OSH managers can access online reports, identify exposure levels and find suitable solutions to address potential risks.

Figure 1: A cartoon-style representation of the system

While workers are wearing the wristwatch, the system's software continuously monitors and provides insights into the vibration levels each worker experiences, with the data presented in a clear and accessible format. This allows individual risks to be identified before exposure compounds and irreversible damage occurs. The system converts the vibration data into HSE metrics and notifies the worker if the vibration level is approaching the acceptable threshold.

The wristwatch provides constant monitoring through automated reporting, including individual daily exposure and tool usage reports. These reports highlight areas of risk and suggest prevention strategies. General Data Protection Regulation (GDPR)-compliant reports are available 24/7 and can be accessed remotely, eliminating the need for paperwork. HSE specialists or designated managers can use their laptops or a smartphone app to monitor exposure levels in real time and intervene, if necessary. This facilitates early intervention and can thus support companies reduce the vibration risk on an ongoing basis. By displaying these indicators in reports, the product manufacturer helps ensure that all parties take responsibility for worker welfare.

2.2.4 Technologies employed in the system

Aside from the wristwatch software, the product manufacturer employs several other technologies. **Error! Reference source not found.** shows these technologies and explains how they are used to e ffectively monitor and reduce workers' exposure to HAV. To prevent HAVS, it is also recommended to use appropriate tools and equipment, take regular breaks and practice good hand hygiene alongside leveraging new technologies.

Based on the initial wristwatch, the company has introduced a third-generation workplace wearable watch, a single device that can allow monitoring and management of multiple industrial risks, as it can:

- gain an accurate insight of exposure to vibration and readily show compliance with limits on vibration exposure;
- keep workers safe with proximity warnings for moving vehicles or equipment;
- create exclusion zones, based on workers' credentials, that is, where workers are permitted to move around the workplace, depending on the tasks they are carrying out;
- send alerts and track lone workers; and
- track worker movements and activity levels.

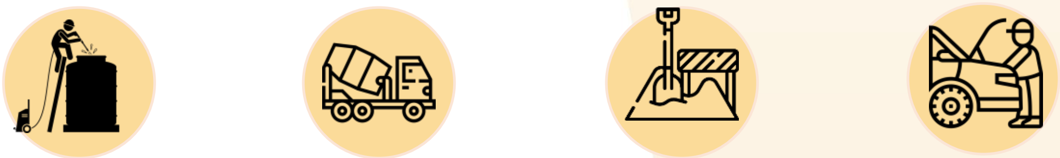
A new development of the wearable offers an improved view of workers' environments and improves **safety and operational efficiency**. For example, the wearable assists in mitigating the effects of HAV exposure by identifying hazardous proximity and near misses in restricted areas, and by sending immediate alerts to workers exceeding exposure limits. This information is collected through the product manufacturer's analytics platform and is used to minimise risk and establish a secure workplace.

2.3 Examples of use

Smart monitoring for HAV helps employers protect their workers from the harmful effects of vibration by providing real-time monitoring and risk assessment, which allows better management of exposure levels and can thus prevent the development of this debilitating condition. As Figure 2 illustrates, the product manufacturer's wristwatch system can be used in several sectors, including **construction, public utilities, heavy engineering manufacturing, grounds maintenance, shipbuilding, mines, industrial cleaning, vehicle repair and many others**, with its main function being preventing equipment and task-related risks.

Figure 2: Applications of smart HAV monitoring device across sectors and tasks

Construction	Shipbuilding & repair	Industrial manufacturing	Mining
Equipment-related risks			
Breakers Grinders	Jackhammers Chipping hammers	Sanders Pedestal grinders	Bolting machines Breakers
Task-related risks			
Drilling Blasting	Drilling Shovelling and digging	Operating sanders Shovelling and digging	Drilling Heavy machinery



Industrial cleaning	Manufacturing concrete products	Roads and railways maintenance	Motor vehicle repair
Equipment-related risks			
Pressure washers Floor scrubbers	Chipping hammers Concrete breakers	Compactors Breakers	Impact wrenches Polishers
Task-related risks			
Using pressure washers Using floor scrubbers	Drilling Clearing concrete	Drilling Blasting	Using polishers Operating sanders

3 System implementation: drivers and barriers

3.1 Motivators and goals

The product manufacturing company began designing HAV monitoring systems in 2005, as a start-up business, following the UK's adoption of EU legislation on exposure of workers to vibration (Directive 2002/44/EC [9]). The directive aimed to ensure the health and safety of workers and to establish a minimum standard of protection for all EU workers through the early detection of adverse health effects that may arise from exposure to mechanical vibration in various industrial sectors, including construction, manufacturing and public services. The directive distinguishes between vibration affecting the hand-arm system and vibration transmitted to the whole body, setting exposure limit values for both types of vibration based on an eight-hour reference period.

According to this directive, employers are **obligated to assess and measure the levels of exposure to mechanical vibration based on technical specifications** provided in the directive's annex. Employers must also consider working practices, equipment and unusual working conditions. The **risk assessment** must be regularly updated, and based on the results, the employer must take measures to reduce risks at the source.

- If threshold values are exceeded, an action plan must be implemented to prevent exposure from exceeding the exposure limit values. This plan may include adequate technical and/or organisational measures to reduce exposure to mechanical vibration.
- If the exposure limit values are exceeded, immediate action must be taken to reduce exposure to below the limit. Employers must also provide workers who are exposed to risks from vibration at work with the necessary information and training.

At the time the legislation was formulated, it was acknowledged that some uncertainty was to be expected. Nonetheless, current technology for measuring vibration is more advanced. For this reason, the wristwatch system considers two significant points of measurement, the TEP and SEP.

To further understand the implications and potential of such smart digital tools, Table 1 presents a set of broader opportunities and challenges related to the development and implementation of smart digital tool, like the wristwatch.

Table 1: Opportunities and challenges related to the development/implementation of the smart HAV monitoring system

Opportunities	Challenges
Potential to improve HAV monitoring	Fast-moving technology
Possibility to upskill the workforce	Complicated legislation (for example, ISO standards)
Possibility to save time in OSH procedures	Shift from paper to digital monitoring

3.2 Drivers

From the product manufacturers' perspective, the HAV monitoring device can be adopted by companies of different sizes.. However, its **uptake is typically higher in bigger companies**, which tend to have the resources, a safety management system with frequent compliance checks, greater awareness and a more organised structure of OSH management.

There are several transversal success factors for the implementation of the HAV monitoring device. The tool is **easy in its use and not intrusive for workers/end-users**, **easy to deploy and maintain (IT and OSH management),** and it offers **training opportunities.**

In the context of the case study, an implementer's OSH representative from a vehicle repair company in the UK explained that they implemented the system primarily because it offers continuous monitoring

[9] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32002L0044

rather than sample-based monitoring, even though this is not mandated by British legislation. According to the representative real-time data and individual reports on users' exposure to vibration improves the **quality and reliability of the OSH monitoring,** especially related to individual differences in HAV exposure. For example, an experienced worker might exercise less pressure on the tool than a worker with less experience.

According to the HSE Manager, **client participation** and involvement in the design and development of smart digital systems for OSH are **key elements in ensuring effective implementation**. The smart HAV monitoring device is no exception. However, since the system's device and software are off the shelf, client participation is particularly relevant in implementation of the system. For example, the wearable system considers the individual worker's weight, height, age and type of task performed.

The person appointed by the employer responsible for the implementation and monitoring of the smart HAV monitoring device is typically an HSE specialist or a safety manager, although this varies across companies, based on their organisational structure and size.

During the implementation phase, the product manufacturer **provides training opportunities** on how to set up the system and interpret the data. Some implementing companies decided to start with a trial in one site before rolling it out across all their sites.

3.3 Barriers

The main barrier to the implementation of the HAV monitoring device appears to be **the clients' IT infrastructure capacity to manage and store data**. To address this barrier, the product manufacturer now transfers all data to the cloud. Another significant barrier is the **doubt or resistance that may arise on the part of the workforce,** as is common with smart digital system that has a monitoring function. Concerns are often **linked to the fear that the device will share data on workers' productivity** or location with managers. As noted earlier, **clear and transparent communication on the purpose and use of the system** can help address such issues.

Workers can be suspicious about how their employers might be using the data created by smart digital systems. To resolve any misconceptions, the product manufacturer's clients (the employer) have been talking to **workers and trade unions**. **Clear and transparent communication on the purpose and use of the system** has been cited as one of the main enabling conditions for workers' trust. In other words, when workers know that the smart digital system is exclusively about health and safety and not about performance monitoring, they are generally positive about incorporating it into their daily work. Employer's responsibility in this is key.

As seen earlier, other challenges relate to becoming familiar with **changing and fast-moving technology**, dealing with **legislation that is often complicated** and managing **the shift from paper monitoring to digital monitoring**.

4 OSH impact

4.1 Opportunities

In the first place, implementing smart monitoring for HAV presents a significant opportunity **to prevent HAVS** at work**.** HAVS can impair workers' ability to perform tasks requiring fine motor skills and, in extreme cases, cause permanent damage to the hands and arms, including tissue and nerve damage as well as musculoskeletal disorders. Considering that one in three European workers is exposed to vibration at work,[10] smart digital systems for HAVS prevention represent a crucial opportunity for improving safety and health.

By identifying and mitigating excessive exposure to vibration, smart monitoring of HAV can also preserve workers' ability to perform tasks requiring precision. This can **reduce the risk of errors or accidents** due to "compromised ability", as well as contribute to **prolonging a worker's career**. This

[10] EU-OSHA – European Agency for Safety and Health at Work, *Report - Workplace exposure to vibration in Europe: an expert review*, 2008. Available at: https://osha.europa.eu/en/publications/report-workplace-exposure-vibration-europe-expert-review

is particularly important given the challenges posed by an ageing population and the workforce shortages in specific sectors.

The real-time, data-driven and customised feedback from smart monitoring of HAV can also help OSH professionals **create custom ergonomic training for their workers** as well as **implement workplace adaptations**, such as replacing, for example, a mechanical (electric) saw with an air saw. At the same time, workers can benefit from HAV monitoring by **correcting hazardous motions** and **learning how to continuously improve their techniques**. For example, in one of the interviews, it was mentioned that tasks that otherwise might have gone unnoticed, e.g. where someone is cutting a side panel out of the van with an air-saw, now are detected by the system and provided to OSH officers to make informed decisions for OSH.

Furthermore, HAV monitoring can contribute to **increasing safety awareness** through active engagement and real-time feedback, fostering a **proactive safety culture.** Based on the new insights, on exposure levels, OSH manager get encouraged to become more proactive and engaged, actively communicating with workers about their exposure levels and proposing measures to improve their safety, for example, with better shift scheduling.

Moreover, the automated data recording of the system can bring additional benefits to organisations, such as supporting **regulatory compliance** by **ensuring accurate documentation** and **simplifying audits**.

In addition to these opportunities, when the COVID-19 pandemic started, the wristwatch integrated a **proximity function to detect the distance between two workers**, 'nudging' them to stay at a safe distance. Developed in response to the challenges posed by COVID-19, the proximity function is a separate upgrade of the system. Therefore, if there is no need to monitor HAV exposure, the company can configure the device to only detect the distance between two workers, without activating the features needed to detect HAV exposure.

4.2 Challenges

Implementing smart monitoring for HAV can also present challenges for the health and safety of workers. One frequently overlooked challenge is the **potential negative psychological impact, as workers may perceive smart monitoring as a tool for performance evaluation**. Additionally, there are **hygiene risks** associated with dirty or inadequately cleaned monitoring devices, which can lead to bacterial accumulation, skin irritation and other concerns. **Privacy and data security** issues also arise, as constant monitoring might make workers uncomfortable and lead to mistrust. As commented in one of the interviews:

> *"Based on trials one-site, the recognition was there that workers wanted to make sure that they weren't being monitored in terms of their location and the work performance. Considerable effort was made to address this concern, provide transparency and so provide reassurance".*

Finally, there is the risk of **over-reliance on technology**, where workers may neglect basic safety practices when the system is not in use. These challenges do not seem too great to be overcome, especially in workplaces with a well-developed safety culture and OSH management in place where worker consultation is adequately taking place.

Based on workers' feedback the **unobtrusiveness of the system, as well as the ease to deploy and maintain is key**. As indicated in one of the interviews

> *"Some people we work with are health and safety individuals within the company. For them, yes (the system) is part of their job. However, for a lot of people, it is not their primary job. Instead, that is building a bridge or a hospital. Therefore, the task that they are asked to do for OSH (i.e. use the wearable) needs to be as easy as possible, making the system reliable and easy to use".*

A cartoon-style representation of the system, including some of the opportunities and challenges for OSH, is presented in Figure 3.

Figure 3: Smart monitoring for HAV exposure: opportunities and challenges for OSH

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5 Takeaways for development and implementation

This section outlines the primary insights for developing and safely implementing smart monitoring for HAV in workplaces. Many of these insights are cross-cutting, as they can apply to multiple systems analysed within EU-OSHA's research.

Takeaways for the development of smart monitoring for HAV in workplaces:

- Participation and involvement with the client, the implementing company, in the design and development of smart digital systems is key to ensure effective implementation. Especially since the system's device and software are off the shelf, client (employer) and workers participation is particularly relevant in implementation of the system
- Use technology that conforms most optimal to regulations and HSE guidance, such as the real-time assessment of vibrations in this case, that reflects the actual usage conditions experienced by an individual, as opposed to solely relying on a predefined standard measure.
- It is advisable for product manufacturers to integrate new functionalities into existing company infrastructure, from concrete hardware, IT/software to (OSH-) management systems and procedures also encourage organisations with limited OSH budgets to take up these systems and prevents migration cost in the future.
- Early anticipation of clients' needs prevents as well unnecessary overload of the clients (OSH and IT) resources, as well existing as systems e.g. for data storage.
- Early involvement and clear communication of end-users/workers on the purpose and use of the system is most important to prevent worker's doubt or resistance for implementation of the system. To resolve any misconceptions, earlier examples of clients have already shown that proactively organised meetings with workers and trade unions with success.

Takeaways for the safe and healthy implementation of smart monitoring for HAV in workplaces:

- Successful implementation of smart monitoring for HAV in workplaces most often hinges on its integration within a comprehensive OSH framework, including, for example, the application of corrective actions (for example, relevant training for workers or replacement of equipment that causes high levels of vibration).
- Consulting workers beforehand is likely to increase acceptance and subsequently reduce incidents of non-compliance.

- Promote easy use of the system by integration in existing systems and working methods. For example, the easier the exposure output can be retrieved via the existing devices of HSE specialists or designated managers (laptops, smartphone app), the earlier interventions are facilitated, to mitigate vibration risks on an ongoing basis. In the same way, the indicators can be displayed in reports, which helps to ensure the employer that all parties take responsibility for worker welfare. Employers and OSH managers are encouraged to become more proactive and engaged, actively communicating with workers about their exposure
- Training is key in terms of enabling workers to become informed with the safe and healthy use of monitoring systems. In this context, assistance from the product manufacturer, for example, in the form of on site or online training or workplace resources, can prove to be beneficial.

List of abbreviations

AI	Artificial intelligence
AR	Augmented reality
HAV	Hand-arm vibration
HAVS	Hand-arm vibration syndrome
HSE	Health, safety and environment
IoT	Internet of things
ML	Machine learning
OSH	Occupational safety and health
SEP	Sensed exposure point
SME	Small and medium-sized enterprise
TEP	Tool exposure point
VR	Virtual reality

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