SMART DIGITAL SYSTEMS FOR IMPROVING WORKERS' SAFETY AND HEALTH

AN OSH SMART CONTROL CENTRE

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

This large company, established in Spain, operates in several economic sectors, such as construction, civil engineering, green energy, real estate, water supply and so on. Currently, the company has offices in over 40 countries. The system under discussion in this case study has been developed to improve the health and safety of the company's workers by allowing event recognition and risk prevention.

2.2 System description

The smart control centre is an IT-based system for advanced safety management. It is a communication and data analysis centre that records information relevant to OSH, such as (internal) inspections, audits, incidents and external factors that impact risks at a workplace. It consists of several integrated elements that can generate reports and information for management, allow early detection of risks and problems, send alarms and notifications regarding potentially hazardous situations, and help plan and control worker safety and wellbeing. The system is capable of monitoring in real time remote sites located in different countries, in real time, in all countries where the company operates and is coordinated by a health and safety department located in the company's headquarters. The basic structure of the system is presented in Figure 1.

Figure 1: The smart control centre consists of four core, mutually linked elements

Combined, these elements allow safety managers to monitor events received from different workplaces simultaneously and plan their activities, such as inspections or interventions, accordingly. The system is proactive, aiding in accident prevention, but also reactive, sending signals and notifications whenever a reaction is required. The data display module allows for fast and efficient communication or intervention in response to an alert.

2.2.1 Data collection

Data collection is a core activity of the system. It collects and curates data on inspections, contracts, and so on, from workplaces at different locations and from external sources, including reports generated by AI. The core technology for data collection and visualisation is based on industrial **software for optimising business processes**. The key source of data input is **automatised internal reports, thus termed 'management appraisal system reports'**. The system is supported by additional software facilitating data collection, and various modules are developed internally. Currently, the company is working on advancing the system, including the use of **AI-based predictive models developed in cooperation with universities**.

I**ntelligent cameras** are also used, which, through **AI-based technology, provide a real-time analysis of images to identify activities that may generate a workplace risk**. The system is **compatible with drones**, enabling broader situational monitoring compared to regular, immovable CCTV cameras while also providing additional image analysis. Among the cases that intelligent cameras can identify are the **proper use of personal prevention equipment**. For example, cameras can alert a worker who is not wearing a safety helmet during construction work. It detects machines and assesses risks based on proximity to workers, dynamically identifying individuals in potential high-risk zones. During the COVID-19 pandemic, cameras were supplemented with an analytical module to support **social distancing.** The system can send alerts whenever the number of people present at a given space exceeds permissible levels. Intelligent cameras send signals to the smart control centre whenever they identify any hazardous situation. **Safety officers at the control centre can immediately and remotely analyse the alert and act accordingly**. Once the signal is received, a safety officer gets detailed information on the issue detected by AI and can automatically connect with

a camera. Furthermore, cameras are equipped with a system of worker identification by uniform, helmet or logo, though such **data are anonymised, and faces on all images are automatically blurred**.

In addition, workers have access to a **dedicated app** that they can use to communicate with each other and fill out simple **surveys on their needs or concerns**. This app collects data and delivers various metrics, such as a daily 'happiness index'. Thanks to those data, safety managers can monitor **workers' satisfaction and motivation and identify stress or fatigue**, which are often a root cause of human errors and accidents.

2.2.2 Data analysis

The data analysis system uses data on incidents, absenteeism or emotional health to identify the trends and tendencies that may signal workplace risks and allow advanced data analysis, including intelligent processing of images. With the support of Machine Learning (ML) and smart algorithms, it is able to significantly increase precision in forecasting undesirable events that could result in a fatal accident or occupational disease. Therefore, generated reports serve as the essential foundation for safety planning and management. **AI is used to generate reports** on the company's OSH performance automatically too. Important data analysis features **include interactive maps and heat maps** that support the system's predictive strength with a geographic.

At the moment a decision scenario simulator is being developed for future planning of critical activities by routinely generating reports on the probability of accidents that consider a broad range of factors in cooperation with scientists from two universities.

2.2.3 Data display and data insight response

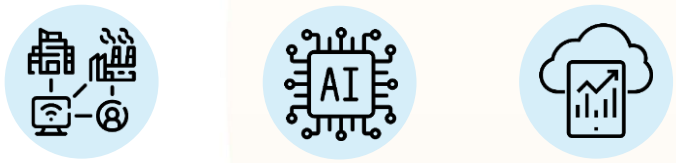
Data display is a key element from an end-user's perspective. The large-scale analytical centre that generates reports on the activities in the company's facilities, such as risks or accidents, including data visualisation. It provides visualisations that show the geographical distribution and intensity of events and interventions, and additional data that could be relevant to OSH, such as weather conditions**.** A **central navigation centre consists of a large display, allowing real-time monitoring of situations and incidents worldwide, accompanied by individual workplaces dedicated to specific analyses.** Several displays are devoted to projects in particular branches of the company such as construction, energy, and water supply. Therefore, they allow users to easily monitor situations on premises worldwide in real time while more effectively targeting preventive actions. For example, during one of the interviews, smart centre end users gave an example of a stress awareness campaign in response to the extreme heat wave in Spain last summer. **Different data visualisations are supported, such as heatmaps, charts, and so on as well as alerts and notifications on relevant events**. Data is displayed in two formats – either at the navigation centre that operates at the company's headquarters or through a mobile app. The final component of the centre is its ability **to respond to data insights**. The smart control centre not only provides safety managers with all the necessary information for effective safety planning and management but also includes communication and notification tools that allow immediate contact with any given office.

Outside the navigation centre, the company uses a **mobile application**, which facilitates the remote use of several analytical tools and **supports effective and real-time communication between the health and safety department, line managers and people at the workplace**. The application is equipped with tools for receiving alarms and notifications and tracking work scheduling. Whenever an alert arrives, or a line manager wishes to consult with the centre about some decisions, she or he can connect in real time with the centre. The centralisation of contacts makes it easier to quickly locate the most relevant expert to support line managers. As a result, **remote visits** requested by line managers are as frequent as regular ones or responses to alerts. The use of **VR and AR** technologies or smart cameras assures smooth communication with workers in the field as well as health and safety managers. **Health and safety managers not only have real-time access to a camera view but also to various tools improving communication, such as taking photos and adding annotations or drawings.** This increases availability of OSH experts in to assess risks for both inspections and advice, while building trust between engineers and safety officers. The navigation centre and remote app share a unified graphical interface that can be adjusted to different views based on user needs. Whenever a critical situation occurs, a map also shows an alarm with its location. The display is fully interactive. Therefore, a manager or an analyst can analyse an alarm and plan an intervention immediately. A

safety technician can also directly link with a given workplace and display an image from a CCTV camera.

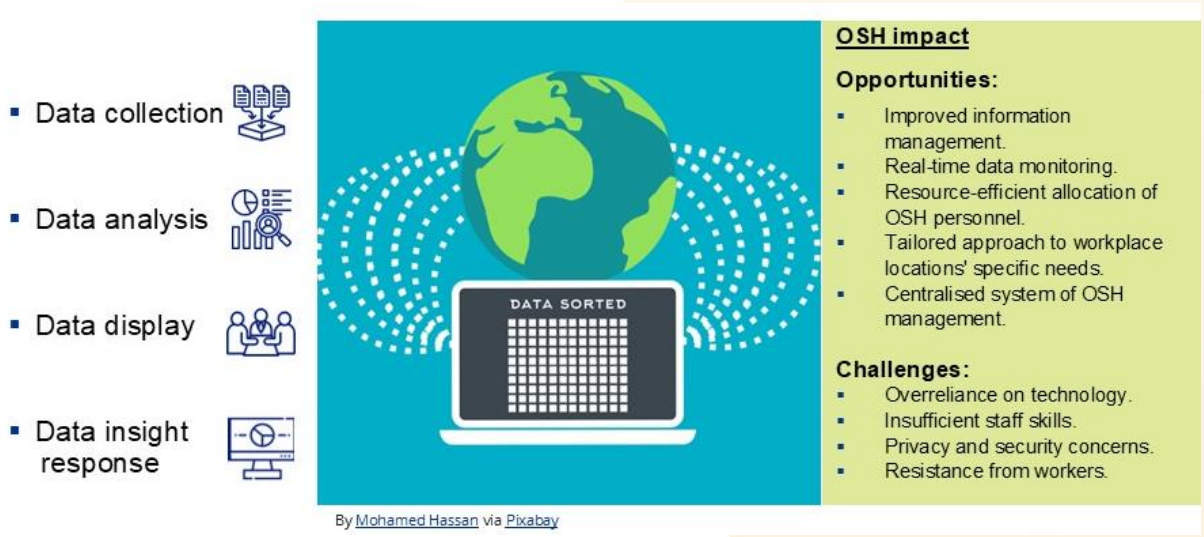
Currently, the **control centre employs several innovative technologies, most notably AI, ML and cloud-based analytics**, supplemented by limited use of IoT (particularly in intelligent cameras), as shown in Figure 3. However, the company is continuously exploring opportunities to develop its tools and integrate other technologies, especially for data collection processes.

Figure 2: Technologies employed by the control centre



IoT	AI and ML	Cloud-based analytics
Intelligent cameras and sensors can automatically detect a potentially hazardous behaviour in real time.	AI-backed ML models can analyse current trends, predict events and signal potential hazards.	The smart control centre collects large amounts of data on health and safety, from both internal and external sources.

Figure 3: Navigation centre



3 Drivers and barriers for the implementation of the system

3.1 Motivators and goals

The company made its first steps towards the smart control centre in the mid-2010s to deal with the increasing challenges due to its scale and goals. With dozens of offices in five countries and hundreds of workplaces worldwide, the company lacked an integrated view of OSH status. Every project and business unit used their systems and collected their own data, which was not always comparable to those in other offices or countries. The idea of the smart control centre was to address those challenges

by having one integrated information system that not only facilitates planning and management but also directly impacts safety at the company.

> *"We have workplaces all around the world. In these workplaces, various information was being produced, including everyday information and detailed reports on particular aspects. At a global company level, we had no view of what was happening".*

The company has been developing the smart control centre for about 7 years. The first stage was to carefully collect all the data in one place and uniform it for **comparability**. Then, the company started the development of a **data visualisation centre**.

However, as workers pointed out in the interviews for this case study, the control centre requires constant development.

3.2 Drivers for implementation of the system

The main driver for implementing the control centre is the growing need to manage **increasing amounts of data on OSH and effectively use them to improve OSH**. Large companies operating in many countries over different continents face both challenges and opportunities to collect diverse data. With too many sources, it is difficult to find any proper information about OSH; therefore, there is a demand for tools to manage information.

Next, **developments in technology, such as cloud services** allow control centres to monitor OSH data worldwide remotely and in real time, and once implemented more flexible than maintaining separate data centres for all relevant workplaces, and at the same time cheaper. Also the recent revolution in AI technologies has been a driver for implementing the control centre. For example, **ML models** can help to prepare detailed forecasts of the company situation and prevent worker risks, and also **AI-driven technologies** to support collecting new data, such as CCTV cameras that recognise unusual workplace situations, became more available.

3.3 Barriers for implementation of the system

The primary barrier to implementing the control centre is high entry costs. The control centre requires several investments for efficient functioning. Most notably, it requires large servers that can store considerable amounts of data. If the centre is expected to run remotely, a significant fraction of the data collected should be available in cloud services that require further investments.

In addition, developing control centres to monitor a large company's key processes is a major undertaking that requires substantial investment. Even though the system is scalable and – with the use of AI or ML can be self-developing – there are significant barriers for companies. The development of the centre is **both costly and time-consuming;** Furthermore, the maintenance of the centre also requires significant expenditures on hardware, software, cloud services, data protection, and so on. The software must be tailored to the company's general needs, as well as to the unique characteristics of each individual workplace.

Moreover, the use and management of the centre asks for **worker's involvement and trus**t in the system, and not in the least for sophisticated skills (in data analysis for example). Therefore **training of OSH personnel and workers** is important, which although relevant can be time consuming and costly.

Effective implementation of the control centre requires training of the current personnel, but also **hiring additional highly skilled staff, such as data scientists.** In addition, engaging workers and managers necessitates technical skills, trust in technology, and a clear understanding of its purpose and implementation. Workers' general digital literacy should be developed which could require training prior to successful implementation.

Due to the necessary investments in resources and expertise needed to implement such systems, at the moment, control centres are generally **dedicated to large companies** that can invest in the essential hardware and software for the effective operation of the control centre. Furthermore, large

companies benefit the most, as they conduct a huge number of processes that are difficult to monitor in traditional ways. Scaling up in the future could possibly make such solutions accessible to SMEs as well.

Other barriers to implementation include the absence of similar systems in other companies to compare and learn from. Since the technology is new, **few companies provide evidence that could serve as a benchmark** for the smart control centre. However, this barrier is expected to diminish with the development and experienced use of the system.

4 OSH Impact

4.1 Opportunities

The company implementing the control centre reports significant improvements in OSH. Most notably, since the first implementation of the control centre, there has been an observable **reduction in the number of workplace accidents**. The rate of incidents fell by 13%, and the number of serious and fatal accidents decreased by 67%. The reduction in incidents may stem from various factors or a combination of issues related to the system's functioning. Still, one of the crucial reasons is the improved capacity to develop, implement and monitor proactive measures, which are in place to prevent accidents.

These developments in accident reduction were possible thanks to **improved reporting and information management**. OSH managers received 9,860 alarms and alerts on working conditions and a further 7,281 alarms related to meteorological conditions. Whenever the centre found any situation that could negatively affect a worker's safety, managers could make decisions on halting production or adjusting it to specific conditions. Furthermore, information generated by the control centre enabled rapid transformation into preventive actions. As a result, the overall number of internal audits increased by 40%, with a greater focus on specific aspects of OSH that are most relevant to each workplace or type of work. The control centre also simplifies the real-time monitoring of corrective actions in response to inspections or incident investigations. Consequently, **the average time required to respond** decreased by almost two-thirds. Notably, real-time monitoring and alerts in this solution allow continuous tracking of safety metrics and conditions, fostering real-time support and resolving possible OSH issues. The real-time aspects are especially important in the case of immediate notifications for safety breaches or hazardous conditions, supporting relevant responses and addressing breaches and hazardous conditions as they arise.

Data-driven communication has been an important factor for successful implementation of the smart control centre. With clear goals and decisions, workers can perceive the company's safety system **as helpful as it is promoting OSH rather than controlling.** OSH managers interviewed informed that they receive a lot of positive feedback from workers on this issue. To achieve this, **workers should participate in the design and implementation process from the very beginning**. System designers report on the consultation with both safety and health controllers, who use the smart control centre to monitor the company's performance and the field workers who are being monitored. Furthermore, the workers of the **health and safety department must be able to receive support from the centre whenever any problem occurs**. As a result of this approach, the number of remote visits to workplaces for internal audits or consultations has increased by 25% since the implementation of the smart control centre. This effect is associated with more requests from workers and line managers rather than increased alerts. Indeed, the smart control centre's functioning can foster communication, creating fast and information-driven communication channels in general. Considering the professionals in charge of OSH in various branches of the company, these **communication channels improve OSH management across different locations**. They enable the allocation of resources, responses and interventions based on specific local needs. From the perspective of OSH managers, this aspect could **support the efficient allocation of safety resources** and personnel in general, while emphasising OSH interventions and inspections within recognised high-risk areas. Also, having access to **transparent and data-driven insight into the OSH workplace** can support identification, development, and implementation of relevant **training programmes**, which can be adjusted to current needs and OSH issues in any given location.

AI and mathematical models will be developed further to enable the **prediction of potential incidents based on historical data and patterns**. With such developments, the control centre's effectiveness in accident reduction is expected to increase: produce forecasts of workplace situations and generate alerts on dangerous situations before they occur, enabling OSH managers to react immediately.

Next, smart control centre activity allows the creation of **tailored OSH approaches to the needs of the specific workplace location**. As discussed above, tailored OSH approaches are twofold. On the one hand, these are based on the data-driven analysis of a particular workplace and its current OSH conditions. On the other hand, tailor-made approaches are related to particular **geographic locations**. For instance, in the case of Spain, OSH personnel could design targeted interventions to address the challenges posed by summer heatwaves.

At the same time, the smart control centre gathers information on all locations, creating a **centralised system of OSH management**. A centralised system supports data comparison across different locations and joint learning from the practices adopted in the given location. Furthermore, a centralised system can support the triangulation of information from different sources, such as data coming from the system, external audits and inspections, standard regulatory requirements, and compliance needs. The centralised system consolidates all essential data in one place, facilitating data extraction and the generation of detailed automated reports adapted to specific needs. This minimises both the time required to gather information and the potential for human errors.

4.2 Challenges

Considering the smart control centre's function and its heavy reliance on data and data consolidation, there is **a risk of overreliance on data by workers and management**. This can lead to challenges, for example in the case of software bugs or hardware failures that hamper reliable functioning. In addition, considering the large amount and different type of gathered data, it is essential to ensure proper analysis, draw relevant and accurate conclusions and understand data gathering limitations.

Plus, while the smart control centre offers complex services, it may be challenging to use the full potential of the technology. Indeed, a company representative mentioned that **digital skills** can be a critical obstacle to the proper use of the technology and OSH data gathered. For these reasons, company representatives mentioned that ensuring digital training for both workers (end-users) and supporting OSH personnel is critical to using technology properly. On the workers' end, the challenges include understanding the system's use, its capacities and limitations, and **effectively using these systems for OSH improvements**. On the OSH personnel end, the identified challenges include handling OSH information properly, reducing the risk of errors due to misunderstanding or misuse of the system and, on the other hand, avoiding an overreliance on the technology.

Another challenge is **worker privacy**. Technologies involving worker monitoring through CCTV cameras, which can identify specific persons and their behaviour are of particular concern. Even though the system automatically blurs faces and other personal data, the implementation has two challenges. First, additional investment in hardware and software is required to protect worker data. Second, the implementation process must consider the **resistance of workers who may feel threatened by being monitored**. Active involvement of workers and their managers (e.g. adequate filling of reports) is a crucial factor in collecting data that would be useful in modelling and supporting OSH in the company, but also ensuring that system is used as intended. Therefore, user acceptance is a key success factor. Clear communication with workers on the objectives of the system, while involving them in the design, can help overcome this challenge. Moreover, **workers with no basic digital skills tend to be more sceptical** towards such technologies. The company's experience demonstrates that, in the case of control centres, investing in the general digital literacy of workers is crucial. On the other hand, training such workers to use advanced technology may be ineffective and a **source of frustration and further resistance.**

For the smart control with this heavy reliance on data, ensuring sufficient protection from **cybersecurity threats** is an important aspect. Data breaches and unauthorised access to sensitive information are risks for large-scale data processing. Especially considering the sensitive OSH data gathered, such as information on high-risk situations or accidents, the development of security systems to protect from any malicious activity is a considerable challenge.

5 Takeaways for development and implementation

This section outlines the most important conclusions on the development and implementation of the control centre, enabling the management of all OSH processes in a large, multinational company. Such solutions may be useful and relevant for other international corporations, particularly those operating in the construction, energy, or mining sectors. By leveraging the opportunities and addressing the new risks, the smart control centre can significantly improve OSH management, leading to safer and more efficient workplaces.

OSH and related factors must be considered on a long-term spectrum. The development of such a system can potentially improve OSH if used effectively.

Takeaways for the development of the control centre suggest that product designers should:

- design products that take into account the company's already existing systems (databases, software) - and not in the least existing OSH management systems-, and customise the products to the company's needs;
- guarantee up-to-date reliability of the systems by cooperation with universities and research;
- ensure workers participation in the design and implementation process from the very beginning, by being informed on goals and decisions and incorporating their needs and possible tailored approaches.
- Ensure that by design, data collection complies with data protection regulations and the system is not used for any other purpose, apart from improving OSH.
- Consider scaling up in the future which could possibly make such solutions accessible to SMEs as well.

Takeaways for the implementation of the control centre suggest that organisations should:

- provide workers with clear and transparent information regarding the installation of such a system: user acceptance is crucial;
- ensure that OSH-related systems should be kept separate from other information management systems, so as to ensure transparency and minimize workers fears that they are being monitored.
- consider the legal aspects regarding data privacy and use of AI and ensure that the system complies with the local legislation.
- invest in the general digital literacy of workers by investing in training, and especially in training for specific groups of workers with low digital skills to prevent distrust to the technology or over reliance ;
- train all OSH specialists and managers on using the centre and introduce it as an integral part of the company's safety management.
- encourage workers to use the centre's tools by addressing concerns about the technology (such as data privacy) and emphasise the importance of improving workers' general digital literacy. Workers are more likely to adopt these tools when they are well-informed about both the benefits and potential risks posed by modern technology.

List of abbreviations

AI	Artificial intelligence
AR	Augmented reality
GDPR	General Data Protection Regulation
IoT	Internet of things
ML	Machine learning
OSH	Occupational safety and health
PPE	Personal protective equipment
SME	Small- and medium-sized enterprises
VR	Virtual reality

Author: Andrzej Żurawski (Ecorys).

Project management: Annick Starren and Ioannis Anyfantis — European Agency for Safety and Health at Work (EU-OSHA).

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