Smart digital monitoring systems for occupational safety and health: workplace resources for design, implementation and use

Report

European Agency
for Safety and Health
at Work

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Introduction

This report provides an overview and assessment of workplace-level resources relevant to the design, implementation and use of new occupational safety and health (OSH) monitoring systems at different workplaces.

The report considers new OSH monitoring systems as those using digital technology to collect and analyse data to identify and assess risks, prevent and/or minimise harm, and promote OSH.[1] Often, these are sensor-based systems that can monitor risks at the workplace. These risks can be **physical** (e.g. extreme temperatures, noise, vibrations, radiation, lighting), **ergonomic** (e.g. repetition of movements, extreme postures), **chemical** (e.g. inflammables, irritants toxics, exhaust emissions, explosive substances), **biological** (e.g. animals, micro-organisms, bacteria, viruses), **psychosocial** (e.g. work-related stress, fatigue, night or shift work)[2] and others, such as **safety risks** (e.g. traffic-related risks). These risks can be associated, among other things, with workers' activity/task, equipment, but also with the work environment (e.g. site layout) and work organisation (e.g. shifts).[3]

Figure 1. Examples of workplace risks[4]

Ergonomic
repetitive movements, extreme postures

Chemical
(inflammables, toxics, emissions)

Workplaces can have several health risks

Physical
(extreme temperatures, noise, vibrations, radiation, lighting)

Psychosocial
(work-related stress, fatigue, anxiety)

Safety
(traffic-, work-, equipment-related)

The above risks are found especially in sectors with high OSH risk, including industrial facilities (e.g. warehousing, manufacturing, oil and gas), construction and mining,[5] although some of them are also

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[1] EU-OSHA – European Agency for Safety and Health at Work, Types, purposes, and uses of digital OSH monitoring systems: An assessment of risks, challenges and opportunities, 2022.

[2] Examples are taken from: ILO. (2018). *ILO code of practice. Safety and health in ports* (Revised 2016). International Labour Office, p. 406. Available at: https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/normativeinstrument/wcms_546257.pdf

[3] ILO. (2018). *ILO code of practice. Safety and health in ports* (Revised 2016). International Labour Office, p. 406. Available at: https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/normativeinstrument/wcms_546257.pdf

[4] Figure based on information from: ILO (2016). Code of practice on safety and health in ports (revised edition) International Labour Office, Geneva., p. 406. Retrieved 23/05/2022 from: https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/normativeinstrument/wcms_546257.pdf . Chemical and physical icon made by Eucalyp from flaticon.com. Ergonomic, psychosocial and safety icon made by Freepik from flaticon.com.

[5] This information is based on the review of product manufacturers' websites and Ecorys interviews with stakeholders.

present in sectors with lower OSH risk (e.g. the services sector).[6] Workplace risks can have negative and often irreversible implications for workers[7] and, more broadly, for the economy.[8] In this context, there is an increasing interest, particularly in high-OSH-risk sectors, in how new OSH monitoring systems can help companies manage these risks.[9] This development calls for the design of pertinent workplace resources and learning what works in terms of effectively integrating these systems at the workplace.

Drawing on the above, the purpose of this report is to provide an overview of and critically evaluate available workplace resources. The report also identifies a number of other enabling factors that can help companies effectively integrate new OSH monitoring systems at the workplace. The report is timely as it is conducted in a period when market penetration and interest around these systems is increasing.[10] For the purpose of the report, workplace resources include any type of product and activity that companies use at the workplace to enable workers to successfully accomplish their tasks and goals while enhancing their safety and health.[11] These products can be audio, visual or written documents, while these activities can be in situ or other types of training or company procedures/processes.

The report is structured as follows:

- Section 2 presents the methods of the report, including a discussion on their limitations.
- Section 3 presents the different types of workplace resources reviewed for this report.
- Section 4 compares and critically assesses the workplace resources reviewed. In addition, it identifies a number of enabling factors contributing to the effective integration of new OSH monitoring systems at the workplace, such as workers' participation and others.
- Section 5 presents the gaps and needs resulting from the comparative analysis and critical assessment of workplace resources.
- Section 6 presents how product manufacturers of OSH monitoring systems (hereinafter also referred to as 'product manufacturers') and their clients (e.g. companies) can work towards ensuring the safe and healthy use of new OSH monitoring systems through the use of pertinent workplace resources.
- Annexes include supplementary information. In particular:
  - Annex 1 includes the workplace resources reviewed.
  - Annex 2 includes a list with key informants who have been consulted for this report.

It should be noted that any references to product manufacturers of OSH monitoring systems or companies in this document are illustrative and by no means represent an endorsement to these parties on behalf of the authors or the European Agency for Safety and Health at Work (EU-OSHA).

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[6] For more information, see: OSHWiki, *Musculoskeletal disorders and prolonged static sitting*, n.d. Available at: https://oshwiki.eu/wiki/Musculoskeletal_disorders_and_prolonged_static_sitting

[7] ILO. (2022). Diagnostic and exposure criteria for occupational diseases – Guidance notes for diagnosis and prevention of the diseases in the ILO List of Occupational Diseases (revised 2010). International Labour Office. Available at: https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---lab_admin/documents/publication/wcms_836362.pdf

[8] EU-OSHA – European Agency for Safety and Health at Work, *The value of occupational safety and health and the societal costs of work-related injuries and diseases*, 2019. Available at: https://osha.europa.eu/en/publications/value-occupational-safety-and-health-and-societal-costs-work-related-injuries-and

[9] EU-OSHA – European Agency for Safety and Health at Work, Types, purposes, and uses of digital OSH monitoring systems: An assessment of risks, challenges and opportunities, 2022.

[10] Based on Ecorys interviews with stakeholders.

[11] Based on information in: Rick, V. B., Rasche, P., Mertens, A., & Nitsch, V. (2022). Workplace health promotion: mHealth as a preventive mediator between psychosocial workplace characteristics and well-being at work. In V. G. Duffy (Ed.), *Digital human modeling and applications in health, safety, ergonomics and risk management. Health, operations management, and design* (pp. 249-265). Springer. https://doi.org/10.1007/978-3-031-06018-2_18

1   Overview of methodology

This chapter includes the methodological approach of the report. To evidence the report, the research team reviewed:

- workplace resources from product manufacturers of OSH monitoring systems and companies using such systems (hereinafter also referred to as 'companies or employers'); and
- workplace resources available at the International Labour Organisation (ILO) database and from social partners.

The research team sought to include workplace resources from a wide cast of product manufacturers and companies to maximise coverage of different new OSH monitoring systems, different risks and different sectors. In total, 92 workplace resources were identified out of which 55 were selected for review based on their relevance. The reviewed resources are available in Annex 1 - List of reviewed sources.

Workplace resources were subject to a comparative analysis based on a comparative grid. The research team chose the dimensions of comparison through an internal brainstorming exercise based on the findings of a sister EU-OSHA report,[12] initial interview and literature review findings, and the feedback of EU-OSHA's project management team.

Next to secondary research, 11 interviews were conducted with key informants, including product manufacturers of OSH monitoring systems and companies using such systems, national OSH agencies and others. Interview data were compared with the findings of the comparative analysis to get a fuller picture of existing practices of integrating new OSH monitoring systems and to fill in potential gaps. The list of key informants is available in Annex 2.

The methodology applied in this report comes with some limitations. In particular, despite extended stakeholder engagement efforts, access to product manufacturers of OSH monitoring systems and to companies using such systems was limited. Therefore, this report relies on workplace resources that were publicly available or otherwise shared by a small number of product manufacturers of OSH monitoring systems and companies using such systems.[13] Therefore, while the workplace resources cast a wide net over a range of new OSH monitoring systems covering a variety of risks, they might not be fully representative of the workplace resources that are available.

As a way to mitigate these limitations, the conclusions of this report have been presented and validated in an EU-OSHA online workshop titled 'New monitoring systems for improving worker safety and health' that took place on 8 June 2022.[14]

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[12] EU-OSHA – European Agency for Safety and Health at Work, Types, purposes, and uses of digital OSH monitoring systems: An assessment of risks, challenges and opportunities, 2022.
[13] Based on self-selection, after invitation from the research team.
[14] More information on the workshop is available at: https://www.euosha-events.eu/Digitalisation/WS_OSH_Monitoring/#introduction

2   Types of workplace resources relevant to new OSH monitoring systems

This chapter presents the types of workplace resources reviewed that can be of relevance to new OSH monitoring systems. An overview of these workplaces resources, their types, sectors and the technologies to which they are referring is available in Table 1.

Table 1. Summary of workplace resources reviewed

Workplace Resource source	No of sources	Codes of practice	Guidance documents[15]	Training Material	Other[16]	Sectors	Technologies
Product manufacturers of OSH monitoring systems	31		10	2	19	Mostly cross-sectoral: industrial facilities (warehousing, manufacturing, etc.), construction, mining, oil & gas, healthcare, agriculture	AI, ML, IoT, wireless (Bluetooth, RFID), sensor and camera-based technologies in wearables/ equipment[17]
Companies using OSH monitoring systems	5		2		3	Construction, engineering, manufacturing	Sensor-based technologies, wireless (Bluetooth, RFID)
International resources (sectoral)	8	6	1	1		Shipping, mining, chemicals, textiles, agriculture, clothing, leather and footwear	Sensor and camera-based technologies
International resources (general)	11	3	5	2	1	Mostly cross-sectoral: industrial facilities (manufacturing), construction, mining, oil & gas, automotive, chemical, agriculture	AI, wearables, IoT, cloud, wireless Bluetooth
Social partner	1			1		Shipping	Sensor and camera-based technologies

[15] Guidance documents can include user/implementation manuals, posters, videos and other materials.
[16] Other documents include case studies, marketing materials and reports.
[17] AI (Artificial Intelligence), ML (Machine Learning), IoT (Internet of Things), RFID (Radio-Frequency Identification).

As Table 1 shows, the majority of workplace resources are taken from product manufacturers (31), followed by international resources (19), which are of general (11) and sectoral (8) nature. A fraction of workplace resources comes from companies using OSH monitoring systems (5) and from social partners (1). For the most part, the workplace resources reviewed referred to new OSH monitoring systems using a wide range of sensor-based systems and technologies: Artificial Intelligence (AI), machine learning (ML), Internet of things (IoT), wireless technologies (e.g. Bluetooth or Radio Frequency Identification (RFID)), and others. These systems and technologies were usually found in wearable devices. It should be noted that the above workplace resources came from a limited number of product manufacturers and a number of international sources from the ILO. The latter did not specifically focus on new OSH monitoring systems. Rather, they were more general codes of practice or training materials related to safety and health, which, however, can support companies to design their own, detailed approach towards OSH.

The following paragraphs summarise each of these types of resources, along with their main characteristics.[18]

Codes of practice provide practical guidance for those who have obligations, responsibilities, duties and rights regarding safety and health in a certain sector. **Nine codes of practice** have been reviewed and all were developed by the ILO. Most of them were focusing on a specific sector (e.g. in the ports sector, in shipbuilding and ship repair,[19] in manufacturing) with a few being cross-sectoral (e.g. textile, cloth, leather and footwear industries)[20] or universally applicable (code of practice on protection of workers' personal data).[21] When referring to new OSH monitoring systems, these codes mostly mentioned camera monitoring systems or other sensor-based systems used to prevent workplace risks (e.g. by improving traffic safety).

Company-level policies are developed in-house by the companies and prescribe workplace health and safety procedures. The review did not identify company-level policies as the research team had limited access to companies. In addition, these policies are often internal or otherwise confidential.[22]

Guidance documents seek to guide companies and their workers on how they can use a new OSH monitoring system. Guidance documents can be (implementation) **videos, posters, user manuals**, short **leaflets** etc. They are usually developed by product manufacturers. For example, a Swedish product manufacturer working in site-traffic safety has developed a short video showcasing how its new OSH monitoring system works in practice.[23,24] Such manufacturers are often working in collaboration with their clients. For example, a United Kingdom-based product manufacturer active in the field of hand arm vibration syndrome (HAVS), noise-induced hearing loss and dust-related industrial diseases has produced, after consultation with one of its clients, a poster providing step-by-step implementation details of its HAVS prevention solution.[25] These documents tend to be short and concise. Finally, a series of international-level publications, mostly from the ILO, provide more general guidance on health and safety that is either universally applicable or applicable to specific sectors. These are comprehensive guidance documents that can help both product manufacturers of OSH monitoring systems and their clients think about how to design their workplace resources.

Training material aims to provide practical training to users/operators of new OSH monitoring systems. Often, there is an overlap between training and guidance material. The review has found a mix of training material from the ILO, product manufacturers and social partners. This material is diverse and covers

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[18] The categorisation of resources should not be seen as clear-cut. For example, several guidance documents also include recommendations.

[19] For the shipping sector, information is also available from the International Maritime Organisation (IMO). For example, see the IMO Maritime Safety Committee, available at: https://www.imo.org/en/OurWork/Safety/Pages/default.aspx

[20] ILO. (2022). *ILO Code of practice. Safety and health in textiles, clothing, leather and footwear*. International Labour Office. Available at: https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/normativeinstrument/wcms_828429.pdf

[21] ILO. (2001). *ILO Code of practice. Safety in the use of synthetic vitreous fibre insulation wools (glass wool, rock wool, slag wool)*. International Labour Office. Available at: https://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/normativeinstrument/wcms_107790.pdf

[22] Based on feedback from Ecorys stakeholder interviews.

[23] Retenua AB · Intelligent Sensor Systems. (2021, August 4). *emitrace® Driver assistance system on forklift truck* [Video]. YouTube. https://www.youtube.com/watch?v=TMbphhyvr0Y

[24] Other examples of guidance documents are also available from other product manufacturers consulted e.g. (in alphabetical order): Makusafe.com, Reactec.com, Soteranalytics.com, Strongarmtech.com.

[25] Poster is internal.

different aspects: from providing more information on HAVS (Hand and Arm Vibration Syndrome)[26] to providing instructions on how to register to a new OSH monitoring system.[27]

Other documents most often include **case studies, marketing materials and reports**, with case studies from product manufacturers being the most frequent. Broadly, case studies explain the implementation and results of the product manufacturers' solutions for clients across different industries. For example, a reviewed case study describes the results of a wearable technology capturing spine and shoulder hazardous movements and risk multipliers that was implemented at a hospital in Australia. The results include, among others, a reduction in hazardous movements and in costs of manual handling training and down time.[28]

Stakeholder interviews shed more light on how workplace resources are usually used. In particular, interview data suggest that apart from the above online or offline material, **companies have numerous means to inform workers about the implementation of new OSH monitoring systems.**

First, most companies appear to place strong emphasis on **having workers/operators test technology themselves**. For example, a company in a high-OSH-risk sector noted that before introducing a new OSH monitoring system at the workplace, week-long tests took place where workers could examine prototypes. These tests offer a great opportunity for workers to get hands-on knowledge about the system and can contribute to higher levels of acceptance.

Second, companies work together with the product manufacturers of the OSH monitoring systems they are using and run **in situ or remote training (or visits)** especially at the first stages of the deployment. In these, there is an open dialogue between product manufacturers, OSH managers and employees to test what works, and to calibrate the system, if necessary. This dialogue is also useful in helping all parties understand what the new OSH monitoring systems can and cannot do. For example, a product manufacturer reported to organise hands-on training on how workers should wear the devices and also to provide manuals and video tutorials that are accessible through QR codes.

Finally, in companies, there are regular meetings between the OSH managers/team leaders and the workers including informal talks or toolbox meetings. These have been described as one of the most effective ways of integrating new OSH monitoring systems at the workplace. Indeed, within companies, **both formal meetings and informal conversations (the 'walks and the talks') help to share tacit knowledge and nurture awareness around new OSH monitoring systems and, more broadly, around safety issues**. This is particularly true for environments where OSH managers and workers co-exist (e.g. in closed systems such as warehouses, where safety and culture is more clearly defined).

3 Comparative analysis and critical assessment of workplace resources

This section includes a comparative analysis of workplace resources. The analysis is divided in two parts. The first part provides a comparative analysis of workplace resources from international sources and social partners. The second part provides comparative workplace resources from product manufacturers of OSH monitoring systems and companies using such systems.

This distinction has been made as these two types of workplace resources are different in terms of scope and thus merit a separate analysis. In particular, workplace resources from product manufacturers and companies are referring explicitly to new OSH monitoring systems and are thus more relevant for their design/implementation. In turn, workplace resources from international sources are more particular to general safety and health provisions, both within specific sectors and also across sectors.

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[26] Reactec Operator Toolbox Talk – Why Hand Arm Vibration is important. Available at: https://documents.reactecanalyticsplatform.com/Training/OperatorToolboxTalkHAVAndSD. See also: https://documents.reactecanalyticsplatform.com/
[27] Reactec Analytics Platform. Operator ID Card Manager. Available at: https://documents.reactecanalyticsplatform.com/Documents/IDCardManagerGuide. See also: https://documents.reactecanalyticsplatform.com/
[28] Soter Analytics. SoterCoach. 2019. Case study at hospital in Perth, Western Australia.

3.1   Comparative analysis of international (sectoral) resources

This section presents the results of the comparative analysis of 20 workplace resources from international sources and social partners. Among them, nine have cross-sectoral coverage, including: manufacturing, construction, mining, automotive, chemical, shipbuilding and agriculture. Another nine resources focus on specific sectors, such as: shipping, mining, waste collection, construction, manufacturing, agriculture and forestry. Two resources did not focus on any specific sector. Table 2 shows some broad takeaways of the comparative analysis.

Table 2. Comparative analysis of international (sectoral) workplace resources

Workplace Resource	Does the resource refer to the types and levels of risks that can occur at the workplace?	Does the workplace resource refer to OSH exposure limits (e.g. noise levels) for types of risks at the workplace (e.g. chemicals)?	Were workers consulted in producing the resource?	Does the resource refer to the need for collaboration between companies and employees for OSH-related issues?	Does the resource address issues on workers' medical (health/OSH) monitoring and personal data?
Total N = 20[29]	Both n = 15 (75%) of the resources refer to both the types and levels of risks Types n = 04 (20%) of the resources refer only to the types Neither n = 01 (5%) does not refer to either the types or the levels of risks	Yes n = 15 (75%) of the resources refer to OSH exposure limits No n = 05 (25%) of the resources do not refer to OSH exposure limits	Yes n = 20 (100%) of the resources mentioned that workers were consulted in producing the resource	Yes n = 19 (95%) of the resources refer to the need for collaboration between companies and employees for OSH-related issues No n = 01 (5%) of the resources does not refer to the need for collaboration between companies and employees for OSH-related issues	Yes n = 13 (65%) of the resources address issues on workers' medical monitoring and personal data No N = 07 (35%) of the resources do not address issues on workers' medical monitoring and personal data

As Table 2 shows, international (including sectoral and social partner) **resources offer a detailed account of different types of risks that are present in different sectors**. The resources associate

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[29] N=20 is the number of resources that were used in the comparative analysis.

these risks with specific activities/tasks and equipment, as well as with how the workplace is designed (e.g. production lines) and how the work is organised (e.g. in shifts). These resources also describe the implications of these risks for different aspects of workers' physical health (e.g. respiratory, skin diseases, occupational cancers) and mental health (e.g. behaviour). For example, ILO (2022) provides a detailed account of occupational diseases by target organ systems and by different types of chemical, physical and biological agents.[30]

In most cases (n=15), resources **refer to both the types and the level of the risks** (e.g. high, medium, low) and present relevant information on **OSH exposure limits** based on risk assessments. Resources on OSH exposure limits are important in terms of raising awareness around the need to perform periodic measurements among stakeholders as occupational exposure to risk factors has negative consequences on workers' health both in the short and the long term. For example, resources explain how acute exposure to poisonous dust and fumes (e.g. benzene concentration above 1,000 ppm)[31] may cause life-threatening conditions, including arrhythmias. Resources also highlight how exceeding occupational exposure limits over the life course can lead to ill health (e.g. lung, liver, kidney, neurological conditions), even when not immediately precipitating acute health conditions.[32]

More broadly, workplace resources aim at **raising OSH awareness and providing direction, guidance and tips** on how to manage risks at the workplace. They are of interest to everyone who has OSH-related rights, duties and obligations in the private or the public sector, and in larger enterprises as well as in SMEs. This includes governments, employers, workers, OSH professionals, physicians, labour inspectorates (i.e. ensuring compliance and adequate working conditions) and so on.

These **resources cover various steps in OSH monitoring**, also taking into account the so-called hierarchy of controls.[33] Therefore, they point to a wide range of different collective measures that can help companies manage risks, based on the risks' nature and level. For example, in the case of toxic fumes and dust, these steps can include **elimination** (i.e. eliminating or reducing fumes and dust at the source), **administrative controls** (i.e. changing the way the work is performed by using wet drilling instead of dry drilling) and, as a last-resort, **using personal protective equipment (PPE)**.

While highly technical in certain cases, resources are clear that following the hierarchy of controls in managing risks is important, and that PPE should be used only when other solutions (elimination, substitution, engineering controls, administrative controls) **cannot be used or adopted.** For instance, when preventive measures fail, promptly terminating exposure to risk factors can reverse unwanted consequences on workers' health (e.g. arrhythmias). **Resources also suggest that general OSH steps and exposure assessments may not be enough**, as individual workers' susceptibility to risk factors can differ. This is true both for workers of the opposite and the same sex. For example, men and women have differences in their immune responses[34] while 'the susceptibility of women to hazardous chemicals can vary based on their reproductive cycles and at different life stages such as pregnancy, lactation, and menopause, when their bodies undergo physiological changes that may affect their vulnerability to health damage from chemicals',[35] psychosocial risks (e.g. stress) can affect different workers in different ways.

In addition to **technical and practical aspects**, these workplace resources also cover **administrative** issues and place emphasis on the context, notably the **legal and policy** dimension (including collective and sectoral agreements). They document good practices, lessons learnt, challenges and opportunities

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[30] ILO. (2022). Diagnostic and exposure criteria for occupational diseases – Guidance notes for diagnosis and prevention of the diseases in the ILO List of Occupational Diseases (revised 2010). International Labour Office. Available at: https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---lab_admin/documents/publication/wcms_836362.pdf

[31] Abbreviation stands for parts per million.

[32] See also: European Chemicals Agency. (n.d.). *Occupational exposure limits*. Available at: https://echa.europa.eu/oel#:~:text=Occupational%20exposure%20limits%20(OELs)%20are,the%20air%20of%20a%20workplace

[33] ILO & IEA. (2021). *Principles and guidelines for human factors / ergonomics (HFE) design and management of work systems*. International Labour Office (ILO) and International Ergonomics Association (IEA). Available at: https://www.ilo.org/global/topics/safety-and-health-at-work/news/WCMS_826603/lang--en/index.htm

[34] ILO. (2021). *Exposure to hazardous chemicals at work and resulting health impacts: A global review*. International Labour Office. Available at: https://www.ilo.org/global/topics/safety-and-health-at-work/resources-library/publications/WCMS_811455/lang--en/index.htm

[35] ILO. (2021). *Exposure to hazardous chemicals at work and resulting health impacts: A global review*. International Labour Office. Available at: https://www.ilo.org/global/topics/safety-and-health-at-work/resources-library/publications/WCMS_811455/lang--en/index.htm

for further improvement, country-specific 'how to' guides; and they refer to the key importance of the inclusion of key national, regional and local actors.

All of these **resources were produced by consulting workers or worker representatives** and almost all **of them referred to the need for the participation of workers in issues related to OSH and the need for collaboration between employers and workers.** In some cases, resources also detail the importance of considering the needs of and involving workers with specific needs (e.g. based on gender, age, migrant status, disability and so on). Checklists provide practical suggestions to support companies and workers to improve OSH at the workplace, through participation and training, for instance. Close, tripartite collaboration has also been referenced in both international resources and the interviews as an important driver that can address concerns around the use of monitoring data and increase the acceptance of new OSH monitoring systems. Data privacy issues include, for instance: the type and amount of data collected, who has access to the data and for what purposes, cybersecurity issues and others. It is worth noting that similar issues (including data privacy, validity and reliability) are also present in traditional ways of monitoring, such as surveys, with some exceptions (e.g. anonymous surveys).

3.2 Comparative analysis of workplace resources from product manufacturers and companies

This section presents the results of the comparative analysis of 36 workplace resources from product manufacturers of OSH monitoring systems and companies using such systems. The majority of these resources include guidance documents and training material as well as other types of documents such as case studies, marketing material and reports. These resources refer to new OSH monitoring systems covering a wide range of sectors such as industrial facilities (e.g. warehousing, manufacturing, retail), construction, engineering, mining, agriculture, healthcare and others. These monitoring systems combine primarily sensor-based technologies with AI, ML, IoT, wireless technologies (e.g. Bluetooth, RFID) and others. They are found in stand-alone wearable devices such as wristwatches, but also in equipment (e.g. in forklifts). The table below summarises some broad takeaways from the comparative analysis.

Table 3. Comparative analysis of product manufacturer/companies' workplace resources

Workplace resources	Does the workplace resource describe the purpose of the new OSH monitoring system?	Does the workplace resource describe the limitations of the new OSH monitoring system?	Does the resource identify OSH responsibilities at the workplace?	Does the resource address issues on workers' medical (health/OSH) monitoring and personal data?
Total N = 36 n = 31 (product manufacturers of OSH monitoring systems) n = 05 (companies using OSH monitoring systems)	Yes n = 35 (99%) No n = 01 (1%)	Yes n = 02 (6%) No n = 34 (94%)	Yes n = 08 (23%) No n = 28 (77%)	Yes n = 05 (15%) No n = 31 (85%)

As Table 3 shows, **all workplace resources provide a description of the purpose of the new OSH monitoring system** in question. This takes place through guidance documents, including short videos, frequently between 1 and 5 minutes, posters and leaflets, but also through technical documents that are

addressed to OSH professionals or IT departments within companies.[36] Therefore, it appears that workplace-level resources are addressing with different means workers and OSH professionals.

Generally, the reviewed workplace resources do not describe the limitations of the systems. However, interview findings strongly suggest that **product manufacturers are transparent and disclose in full the limitations of their products to their potential and existing clients**. More concretely, the product manufacturers interviewed reported they fully disclose the limitations of their systems to their clients to avoid misinterpretations that can have negative consequences for workers' safety and health. These consequences can be far-reaching, especially as the clients of these systems are generally large companies, often employing thousands of employees. In fact, in many cases, product manufacturers and their clients (i.e. companies) reported to work together to test and reduce the often inherent limitations of these systems.

Since the majority of the resources come from product manufacturers, in most cases the **workplace resources neither identify OSH responsibilities at the workplace nor refer to an OSH management system**. However, this is expected, as product manufacturers cannot define the OSH procedures of their clients, but rather aim to augment them via their products. Nevertheless, there are workplace resources that make reference to compliance responsibilities on behalf of companies (e.g. compliance with OSH exposure limits). In some cases, the product manufacturers' workplace resources make a reference to the existing national or supranational regulations as well as to OSH. For example, one resource references the United Kingdom's 'Control of Vibration at Work Regulations' introduced in 2005. These regulations include an Exposure Action Value (EAV) and an Exposure Limit Value (ELV) based on a combination of the vibration at the grip point(s) on vibrating equipment and the time spent using it.

Workplace resources from product manufacturers/companies rarely touch upon data issues (e.g. who has access to the data, what are the implications of data collection for workers, issues around cybersecurity and so on). Equally, such resources **rarely consider issues in relation to special categories of workers**. Section 4.3 provides some potential explanations for the above findings. Broadly speaking, although issues around data appear to be at the heart of the discussions when it comes to new OSH monitoring systems, there is evidence suggesting that data issues are often troubleshot through tripartite involvement and that workers are generally positive about OSH monitoring systems when issues around the use of data and cybersecurity are clear.

On another issue, workplace resources from product manufacturers/companies often **refer to both the type and level of risk** (e.g. ergonomic, chemical, biological, psychosocial) that can occur at the workplace. Among these, many also include OSH exposure limits (e.g. noise and vibration levels) as specified in international and EU legislations on OSH-related issues. In addition, while workplace resources reviewed are about new OSH monitoring systems that can often be applicable to specific sectors, **they generally tend to focus on prevention of a particular type of risk** (e.g. musculoskeletal disorders).

Finally, a large number of workplace resources (19) include **case studies or reports showcasing the application and results of new OSH monitoring systems across different sectors**. For example, one resource by a product manufacturer assessed the impact of exoskeletons by comparing the performance with and without the exoskeleton using AI algorithms based on ISO standards and has shown that exoskeletons reduced the workload by 27%.[37] Similar results have been obtained by an OSH monitoring device that provides real-time audible and vibration biofeedback alerting workers of any hazardous movements they made. Results have shown that the device reduced hazards that lead to injury by 31%. While this is true, having a counterfactual situation providing concrete evidence on the effectiveness of new OSH monitoring systems is not possible for all new OSH monitoring systems.

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[36] Based on Ecorys interviews with stakeholders.
[37] WearHealth. (2021). *Case study. Exoskeleton evaluation.* Available at: https://wearhealth.com/wp-content/uploads/2021/05/exoskeleton-evaluation-case-study-e-distribuzione.pdf

3.3 Critical assessment of workplace resources

This section critically assesses the workplace resources presented in the previous sections.

Overall, international (sectoral) resources seem to be the most useful in supporting workplaces when structuring their own detailed, equitable and participatory approach to OSH monitoring. They are important in terms of making different stakeholders aware of OSH risks and their management based on the hierarchy of controls, the residual role of PPE (and the need for PPE to be user-centred), the regularity of risk assessments and so on. They provide an overview of different dimensions of interest and give indications and guidance on 'what to do', 'who should take action' and 'how' – in terms of improving OSH in the workplace, with attention to risk factors, the OSH life cycle, the importance of context and issues revolving around worker participation. Despite the positives, ILO resources are pitched at a fairly general level. These resources are comprehensive and useful in providing a bird's eye view but cannot replace resources by product manufacturers and companies (e.g. guidance, training materials and so on).

For the most part, the latter are specific to a particular new OSH monitoring system and its application at the workplace. These resources are usually shorter when addressing workers and longer when addressing OSH professionals. For example, videos addressing workers, which present step-by-step implementation instructions, are usually short. Equally, posters with the same function are usually simple, including visual cues. In turn, workplace resources addressing OSH professionals can be longer, for example, documents including information on data management or software administration.[38] In general, product manufacturers use various workplace resources either in a stand-alone or in a complementing way. For example, product manufacturers and their clients (e.g. companies) can include in situ trainings or posters together with an on-demand, online training available through a QR code. Companies reported that using a mix of resources (e.g. posters, videos, trainings) can benefit the integration of new OSH monitoring systems at the workplace.

Figure 2. Example of a poster from a product manufacturer of an OSH monitoring system

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[38] For example, Reactec. (2022). *Software administration guide*. Available at:
https://documents.reactecanalyticsplatform.com/Documents/SoftwareAdministrationGuide

When it comes to workplace **resources that can provide workers with information on acceptable OSH exposure limits** (e.g. in relation to physical, ergonomic or other types of risks), these are for the most part international resources and not resources developed by product manufacturers of OSH monitoring systems and their clients. The report does not have evidence on whether workers are knowledgeable about exposure limits through these international resources or through other means (e.g. national workplace resources, trade unions) and it also cannot comment on the type of workplace resources that would be best suited to raise awareness around these issues.

Generally, workplace resources from product manufacturers/companies do not include the limitations of the new OSH monitoring systems. One explanation could be that workers might be aware of the limitations of the different systems, as often they take part in the selection, testing and optimisation of these systems, or familiarise themselves with them through regular meetings with their team leaders/OSH managers as part of their work.[39] Indeed, all companies interviewed reported to first test new OSH monitoring systems with workers. Often, testing takes place through a small-scale pilot before full-scale implementation. Another explanation could be that workplace resources addressing workers have a narrow scope on how to implement a new OSH monitoring system and therefore might not be the appropriate template to list these limitations. Research with workers using new OSH monitoring systems can help ascertain whether this limitation is important.

The same holds for issues in relation to data. **Generally, workplace resources from product manufacturers/companies do not include information around the use of data** such as data transparency, security and privacy. This is one reason that explains why data protection is often considered as a topic separate from OSH, treated by the IT departments of companies. Another explanation could be that issues around the use of data are normally treated before the introduction of a new OSH monitoring system to the workplace through tripartite involvement, as prescribed by all ILO sectoral resources. In particular, in some countries[40] there is a strong legal framework where employers have a legal obligation not only to inform but also to negotiate with workers the introduction of a new technology at the workplace. However, even when this is not the case, product manufacturers and companies reported that usually consultation with workers takes place when there are changes in OSH procedures as this improves acceptance of the new procedures/systems. More concretely, product manufacturers and companies reported that as long as the issues around the use of data are clear, workers are generally positive about monitoring systems that can improve their safety and health. Overall, these stakeholders noted that **several provisions are in place to address issues around data**. For example, in many cases, data is gathered anonymously and analysed at an aggregate level, with the prior consent of the workers. In other cases, data is stored on hard drives where access is available only to the workers' union and can be made available to other parties only in exceptional circumstances such as accident investigation. In addition, some new OSH monitoring systems do not use personal identifiers. These provisions do not change the fact that workplace resources, at least those targeting workers, generally do not include information around the use of data. The same might not be true for the technical departments of companies (e.g. IT department) that usually receive documentation from the product manufacturers of OSH monitoring systems around data issues.

In conclusion, **while there is a wide range of workplace resources relevant to health and safety, workplace resources relevant to new OSH monitoring systems are scarce and, for the most part, available from product manufacturers and companies**. Workplace resources from product manufacturers/companies addressing workers are short, simple and relevant for the implementation of a new OSH monitoring system at the workplace, while the same resources addressing technical staff/OSH professionals are more elaborate. Many of these sources are confidential.

In general, the comparative analysis revealed that international (including sectoral) resources are wide in scope and do not include much information on new OSH monitoring systems. In turn, product manufacturer/company resources are narrow in scope (i.e. specific to the monitoring system) and sometimes lack information on important issues such as OSH exposure limits, systems' limitations and data. The report cannot ascertain whether this information is found by other means or is otherwise unnecessary to be included in these resources.

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[39] Ecorys interviews with stakeholders.
[40] Based on Ecorys interviews with stakeholders. Examples include Germany and Italy.

The comparative analysis considers a small sample of companies and thus does not have conclusive evidence on whether workers are consulted when it comes to the design or implementation of workplace resources. In general, it seems that this can vary. For example, a company reported that they take stock of opportunities such as the international safety day to give their workers across different facilities in the world the opportunity to showcase their best practices in relation to safety (e.g. presentations/posters on how they manage OSH risks).

Data from the interviews suggest that apart from the above resources, companies use numerous other means to implement new OSH monitoring systems at the workplace. As noted in the previous section, these include **involving workers in the testing, selection and optimisation of the new OSH monitoring system, in situ or remote trainings, as well as regular meetings with the OSH management professionals/team leaders**. Last, but not least, it is worth noting that some new OSH monitoring systems can also provide **on-the-job, real-time feedback** to workers that can help them address risks whilst working. For example, a new OSH monitoring system that was reviewed can provide discrete but tangible indications (e.g. buzzing) when workers are performing a task in an (ergonomically) unsafe way and provide them with feedback on how to improve task performance. A case study looking into the impact of this system has reported up to a 46% reduction in ergonomic injuries for new hire package handlers in a major logistics firm in North America.[41]

Often, product manufacturers, their clients (i.e. companies) and workers work side by side in implementing a solution and understanding what works well and what works less well through in-person or remote (during COVID-19) trainings that can be weeks long. In addition, companies often involve workers in testing, and they have regular team meetings (e.g. before the start of a shift) in which workers share their tacit knowledge and discuss potential issues associated with the new OSH monitoring systems.

Finally, irrespective of the workplace resources, at least two enabling conditions for the effective integration of new OSH monitoring systems have been reported. The **first is workers' buy-in**. Stakeholders strongly suggested that top-down approaches are often less successful. Instead, workers are more likely to accept and effectively implement new OSH monitoring systems when prior consultation takes place. A company representative reported that having workers test and act as ambassadors of the technology among their peers (through explaining the usefulness and so on) has proven to be a particularly successful bottom-up solution that led to higher acceptance. **Second is the broader OSH framework of the company.** New OSH monitoring systems augment rather than replace existing new OSH frameworks. Companies having a strong safety culture and an open channel between workers and OSH professionals working on the ground are more likely to effectively implement new OSH monitoring systems. This is in line with a recent EU-OSHA report highlighting that the introduction of new OSH monitoring systems should not lead to a negligence or substitution of existing OSH procedures.[42]

4 Gaps and needs in workplace resources developed in relation to new OSH monitoring systems

As noted earlier, this review suggests that resources for OSH monitoring systems available at workplaces have mainly been developed by product manufacturers and their clients, aimed at supporting the introduction and use of such systems. These resources typically relate to practical and technical aspects of such systems, whereas European and national OSH resources – highlighting issues of public interest (e.g. privacy and ethics) – tend to be much less used. This section presents the gaps and needs in relation to the above resources and, more broadly, in relation to the effective implementation of new OSH monitoring systems.

A first issue is lack of knowledge sharing. Companies have documented but also tacit knowledge on what works well and what works less well when it comes to the implementation of new OSH monitoring systems, with some companies having their own learning mechanisms. Companies may also have

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[41] StrongArm Technologies. (n.d.). Reducing new hire turnover at a major North American logistics firm. Internal documents.
[42] EU-OSHA – European Agency for Safety and Health at Work, Types, purposes, and uses of digital OSH monitoring systems: An assessment of risks, challenges and opportunities, 2022.

procedures to share lessons learnt across different facilities/plants. Despite the above, cross-company dialogue is often missing. Therefore, there is a **need** to tap into this knowledge and work towards creating a knowledge exchange forum for companies. This forum could take the form of online or in situ meetings between OSH team leaders in different companies. As companies within the same sector are likely to face similar risks, sectoral initiatives inviting interested companies in knowledge exchange activities can be a positive development for the effective integration of new OSH monitoring systems at the workplace. At the same time, initiatives at European level can also provide a learning platform for companies regarding OSH issues. These initiatives exist already and include seminars on specific types of risks, specific tools and various other issues in relation to OSH.[43]

A second issue relates to the extent to which new OSH monitoring systems meet **the needs of vulnerable workers**, including those with mental or physical disabilities, old/young workers, migrant workers and pregnant women, among others. In some sectors where hard labour is carried out, such as construction and mining, a lack of resources for vulnerable groups may be justified, as they should not engage in such work. However, this does not change the fact that there is a **need** for product manufacturers and employers to also consider these workers when implementing new OSH monitoring systems. For example, in construction sites with workers of different ethnic minorities, a good practice is to include material in different languages to ensure that all workers have access to and understand the related new OSH monitoring system. Among analysed workplace resources for this project, only a fraction included references to the needs of vulnerable workers, and these were international-level resources.

A third issue relates to the need to produce workplace resources that are accessible and relatable to workers. Stakeholders stressed that offline resources (e.g. manuals, posters) can still be perceived as the most accessible among workers. These days, many resources developed for workplaces tend to be issued in digital formats, excluding some workers. Primarily parts of the older workforce, and even some young workers, may not have the required digital skills to effectively benefit from or use modern workplace resources. In some cases, workers may struggle with obtaining and using information available on ubiquitous digital equipment such as smartphones or tabloids. Low self-esteem and poor digital skills among workers may lead to resistance when more advanced technologies are introduced. In this context, it is worth noting that a good practice that was reported is featuring actual workers in workplace resources (e.g. in videos, posters), to make them more relatable to their colleagues. Therefore, when developing workplace resources, care and consideration is **needed** for workers with different levels of digital competence.

Figure 3. Including companies' own workers in workplace resources. A good practice example

A fourth issue is one of information. According to interview data, there is a need to inform workers about their rights and responsibilities in relation to new OSH monitoring systems. This also includes issues around the use of data: especially regarding why, how and by whom the data will be used and

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[43] For example, see EU-OSHA's seminar reports, available at: https://osha.europa.eu/en/tools-and-resources/seminars

protected. More broadly, workers **need** to be well informed and engaged during the selection and implementation phases. One company described how their workers get to trial technology that may be implemented in common spaces such as the canteen and coffee area, where the equipment is placed for testing. Accordingly, workers are given very direct opportunities to try out new technologies, while being given the chance to approve or disapprove new systems. This empowers workers and can help increase acceptance. This is in line with research suggesting that positive experiences with technology tend to coincide with workers participating in choosing the device and informing them about the use of data.[44] **These findings suggest that workplace resources for OSH monitoring systems may benefit from involving two-way communication and interactive elements, as the effective dissemination of workplace resources depends on human factors, including sense of participation and trusting those who are behind the technology.**

As a final example of a gap in workplace resources, stakeholders from both public and private sectors stress the lack of standardisation as an impediment in the development of effective workplace resources. With a plethora of different OSH monitoring systems available, resources tend to be either too broad or narrow in scope, while not being aligned to categories or taxonomies of technologies. When it comes to exoskeletons for example, Member States are currently using different standards, preventing the development of shared resources to be used across the EU.

All in all, the above are the main issues identified through this review. A summary of these issues is shown in Table 4.

Table 4. Summary of gaps and needs[45]

Summary of gaps and needs		
Knowledge exchange	Gaps	Cross-company or cross-sectoral dialogues on new OSH monitoring systems is limited-company or cross-sectoral dialogues on new OSH monitoring systems is limited
	Needs	Sectoral initiatives for knowledge sharing/peer-learning activities between companies can help bridge knowledge gaps
Addressing vulnerable workers	Gaps	Provisions for vulnerable workers are often given less attention
	Needs	The design of new OSH monitoring systems should give more attention to vulnerable workers
	Gaps	Gaps might exist when corporate clients do not consult with workers beforehand and

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[44] Jacobs, J. V., Hettinger, L. J., Huang, Y.-H., Jeffries, S., Lesch, M. F., Simmons, L. A., Verma, S. K., & Willetts, J. L. (2019). Employee acceptance of wearable technology in the workplace. *Applied Ergonomics*, *78*, 148-156.
[45] Icons, from top to bottom, made from Nualnoi Kinkaeo, Freepik, Eucalyp, Smashicons and Dreamstale from https://www.flaticon.com/

Summary of gaps and needs		
		try to push solutions in a top-down fashion
Taking into account the real needs of workers	Needs	There is a need to take into account the reality of the workplaces and the workers. Continuous and further consultation is essential for any changes in OSH procedures is essential
Providing information on responsibilities, data and limitations	Gaps	Workers may not be aware of their rights, responsibilities and other important issues in relation to new OSH monitoring systems
	Needs	Resources should appropriately address information gaps around new OSH monitoring systems in relation to data (e.g. interpretation, privacy, transparency, cybersecurity), rights, responsibilities and limitations in a way that is accessible and relatable to workers
Pace of technology and standardisation issues	Gaps	The pace of technology makes difficult to develop up-to-date workplace resources
	Needs	There is a need to strengthen dialogue between private and public parties to better understand the implications of technologies. In addition, there is a need develop common standards in order to develop shared resources across the EU

5 Conclusions: How can workplace resources ensure the safe and healthy use of OSH monitoring systems?

Resources at the workplace have the potential to empower workers and employers to successfully accomplish their tasks and goals. Workplace resources can thus increase wellbeing and compensate for, or even change, negative aspects of work demands.[46]

Workplace resources can include important information such as the purpose of the new OSH monitoring system, implementation instructions, limitations, exposure limits, privacy issues, rights and responsibilities. The review suggests that this information is often found in different documents and thus a comprehensive, yet short, guide might be of benefit to workers.

The review highlighted **several issues going beyond workplace resources**.

In particular, stakeholders emphasised that irrespective of the workplace resources that are in place, effective integration of new OSH monitoring systems relies also on the existing OSH structure and safety culture within companies. Companies placing emphasis on safety and health and having OSH professionals working close with workers on the site are more likely to effectively integrate those systems. In practice, this often translates to clear steering from the OSH leadership, through company-level policies, a well-defined OSH management system,[47] direct communication with workers, and a mix of accessible and relatable workplace resources – all of which are essential pieces of an OSH puzzle and can have a positive impact on the integration of OSH monitoring systems within an OSH management structure. To illustrate the point, in a company that does not place emphasis on safety and health, workers may overlook workplace resources (e.g. skip the training steps in an online guide explaining how to improve ergonomics). This highlights that new OSH monitoring systems and workplace resources are part of the solution, but not the solution itself.

Equally, companies involving workers in the process of selecting, testing and implementing new OSH monitoring solutions are more likely to be successful. A major product manufacturer from Europe confirmed how important it is to get buy-in from all involved, which can include a wide range of stakeholders, including the workers' council, the labour union, worker safety representatives, ergonomists, operation manager, the innovation manager, the site manager and the production planner. In this context, communication needs to be tailored to each of these in manuals, questionnaires, videos, data consent forms, in-person training and so on, to ensure an efficient and seamless implementation of the OSH monitoring systems at the workplace. To this end, a stakeholder reported gathering the opinions from workers on how to improve workplace resources (e.g. checking whether wording/graphics are ambiguous) and <u>make changes to achieve or approximate this</u>.

Finally, nurturing knowledge sharing both within and between companies and sectors can also be a critical factor in integrating new OSH monitoring systems at the workplace. Regular team meetings between workers and between workers and OSH professionals/team leaders (e.g. at the beginning of shifts or at different intervals) can help tap into the tacit knowledge of workers and nurture a safety culture in the workplaces. Disseminating this knowledge across companies and sectors through knowledge sharing activities can also be a positive development that can help the effective integration of new OSH monitoring systems at the workplace.

All in all, workplace resources are an important factor in ensuring the safe deployment as well as the safe and healthy use of new OSH monitoring systems. Further research can shed more light on workers' expectations of these systems and sequentially of the workplace resources needed to effectively integrate these systems at the workplace.

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[47] For example, see the Norwegian Federation of Industries' OSH management e-tool. For more information, see: https://everdier.no/

6 Annexes

6.1 Annex 1 - List of reviewed sources

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6.2   Annex 2 - List of key informants

Ecorys is grateful to the key informants who have agreed to share their insights in relation to WP1T3 research. The list of key informants is in the table below.

	Name	Position	Organisation	Type
01	Andreas MÅRTENSSON	Board Member, Employee representative Unionen	Boliden/Unionen	Trade Union
02	David DUWE	Vice President	Ottobock	Product Manufacturer
03	Erik DAHL-HANSEN	Assistant Director, Occupational Health	Federation of Norwegian Industries	Employer's organisation
04	Jacqui MCLAUGHLIN	CEO	Reactec	Product Manufacturer
05	Jonas ARULF	Administrative Terminal Manager	Yara International	Company
06	Malik TIRMIZI	Global Head of Business	Ottobock	Product Manufacturer
07	Mattias IMMENDÖRFER	Business Development Consultant	Ottobock	Product Manufacturer
08	Marco BORDIGNON	Technical Manager, Partner	Ergocert	Certification Institute
09	Mark CULLEN	Assistant Chief Executive Officer	Health & Safety Authority, Ireland	Health and Safety Authority
10	Mikkel HEIEN BJONGE	Chief Adviser	Federation of Norwegian Industries	Employer's organisation
11	Peter BURMAN	Program Manager Mine Automation	Boliden	Company

	Name	Position	Organisation	Type
12	Rafael MOSBERGER	CEO	Retenua	Product Manufacturer
13	Rudolf DE BRUIJN	Director, Health and Safety	DAF Trucks	Company
14	Mike SPINELLI	Chief Innovation Officer	StrongArm	Product Manufacturer
15	Winson YEUNG	Principal Consultant	Occupational Safety and Health Council, Hong Kong	Health and Safety Authority

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