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Advanced robotic automation: comparative case study report

Report

European Agency for Safety and Health at Work

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1 Introduction

Automating tasks through technological advancements has been an ongoing process in many industries. This development can also significantly impact occupational safety and health (OSH) in a work environment. It allows removing workers from hazardous situations and improving the quality of work. This can be accomplished by automating repetitive and strenuous physical tasks with accurate and tireless machines like intelligent and artificial intelligence (AI)-based robotic systems or by automating cognitively strenuous tasks through AI-based information and communication technologies (ICT). Some tasks might not be fully automated, but workers can still receive support through, for example, cobots, which are collaborative robots operating in a shared space with workers. **An increasing number of companies employ AI and/or advanced robotics.** Although still in their infancy in terms of deployment, AI-based systems for the automation of both cognitive and physical tasks, as well as intelligent cobots, show promise in a variety of sectors. However, more information is needed about how they are implemented and managed in the workplace to help ensure their safe and healthy implementation in present, as well as in future, applications.

The European Agency for Safety and Health at Work (EU-OSHA) has developed a number of case studies with the aim to investigate the practical implementation of AI-based systems for the automation of physical and cognitive tasks and of intelligent cobots in the workplace, **their impact on workers, how OSH is managed in relation to such systems, and to gain a better understanding of the drivers, barriers and success factors for the safe and healthy implementation of these systems**. To identify those case studies, several key informants at the EU and international levels, such as workers' representatives and industry associations representing the targeted sectors, were consulted. This consultation and interviews will involved stakeholders resulted in 11 case studies (ID1-ID11) that were fully developed and another 5 shorter case studies (ID12-ID16), that include only basic information, focusing on workplaces that are actually using these technologies.

This comparative report is based on these 11 case studies (ID1-ID11) and includes short descriptions and categorisations of each case study. Furthermore, it contains a detailed analysis of the systems' impact on the workers, work environments and tasks. Based on the case studies, there is an overview of all identified opportunities and challenges associated with the named technologies. The findings of the case studies are also contextualised with the results of the preceding literature analysis included in EU-OSHA's publications on advanced robotics and AI based systems for the automation of tasks[1,2,3], with a focus on where practical experience might deviate from current research trends.

2 Methodology

For this work, an initial assessment questionnaire was developed. The questionnaire contained four multiple choice and 16 open format questions regarding the technology a company uses, what type of task it automates and questions regarding OSH risks and opportunities. The research team identified potential candidates and contacted them to inquire about their participation in the project. Companies were then sent the questionnaire to complete on their own time. These answers formed the basis of 16 cases, that included only basic level of detail. Out of these, 9 were invited and agreed to participate in the extended scheme of interviews for the development of the case studies (two companies were of sufficient size to contribute two case studies of different technologies). The following interviews were targeted at people in the following positions (or their equivalent in any given company): **management, health and safety engineer, data protection officer, worker/workers council member and technical engineer**. The interview guideline had three major sections. Section one covered the general information on the company and their implementation process with a total of seven questions, section two addresses the automated task with six questions and the final section addresses the OSH impact

[1] EU-OSHA, 2022: *Advanced robotics, artificial intelligence and the automation of tasks: definitions, uses, policies and strategies and Occupational Safety and Health*.

[2] EU-OSHA, 2022: *Advanced robotics and automation: implications for occupational safety and health*

[3] EU-OSHA, 2022: *Cognitive automation: implications for occupational safety and health*

of the system. The interview guideline was translated into three languages. Each interview had a duration of 1-1.5 hours and was performed with the written consent of the participants. The answers were completely anonymised. Based on the interview results detailed case studies were developed. To better contextualise their answers the taxonomy developed by EU-OSHA[4] specific in categorising different types of technologies based on important criteria of AI-based systems and advanced robotics was used. These 11 case studies form the basis for this comparative report, which presents the most important collective findings of the case studies. It also formulates recommendations for the successful implementation of advanced robotics or AI-based system and their impact on OSH.

3 Companies overview

A total of 9 companies participated in the case study scheme of interviews, providing a total of 11 case studies (ID1-ID11). They are primarily located in Europe, however, many participants operate internationally, and one case study comes from the United States. Larger companies could contribute with more case studies to the project as long as they were referring to distinct technologies, automating different tasks.

Based on the taxonomy of AI-based systems and advanced robotics developed by EU-OSHA[5] and further analysis, Table 1 presents a short overview on the companies and key descriptive information on them.

Table 1: Overview of participating companies, technology and tasks automated

CS-ID	Company	Country	Sector*	Size**	Technology	Task
1	Automotive and industrial supplier	Slovenia	Manufacturing	Large	Advanced robotic system	Lifting workpieces for inspection
2	Automation integrator	Sweden	Manufacturing	Medium	AI–robot hybrid sawmill	Quality control and physical handling of lumber
3	Energy and automation company	Germany	Manufacturing	Large (100k+)	Advanced robotic system + AGVs	Assembly task + material delivery
4	Energy and automation company	Germany	Manufacturing	Large (100k+)	AI	X-ray-based product inspection
5	Automotive supplier	Portugal***	Wholesale and retail trade; repair of motor vehicles and motorcycles	Large (100k+)	Advanced robotic system	Sewing bags
6	Vehicular automation start-up	USA	Construction	Small	AI	Trenching, via automated excavator

[4] EU-OSHA, 2022: Advanced robotics, artificial intelligence and the automation of tasks: definitions, uses, policies and strategies and Occupational Safety and Health

[5] Ibid.

CS-ID	Company	Country	Sector*	Size**	Technology	Task
7	Technology developer	Denmark	Electricity, gas, steam and air conditioning supply	Large (40k+)	AI–robot hybrid	Image analysis and pick and place
8	Governmental research facility	Germany	Professional, scientific and technical activities	Large (500+)	AI	Image analysis of hazardous substances
9	Oncological centre	Germany	Human health and social work activities	Large (3k+)	AI	Video feed analysis
10	Gas infrastructure operator	Norway	Electricity, gas, steam and air conditioning supply	Large (350)	Advanced robotic system	Gas vessel inspection
11	Agricultural technology developer	Netherlands	Agriculture	Large (2k)	Advanced robotic system	Manure cleaning

*based on the NACE Rev. 2 sector distribution
**company size categorisation is based on the OECD categories on enterprise business size[6]
***the case study is located in Portugal, the company operates internationally

Below, each case study is described in more detail, however, for a complete description, please turn in each referenced case study's full document.

CS ID1	SLOVENIA	COBOT
The Slovenian-founded company operates on a global scale in the field of automotive and industrial technologies. They are a developer and a development supplier of state-of-the-art systems for industrial technology and electrical engineering. At one of their Slovenian factories, the company has introduced a cobot whose primary purpose is to support workers in lifting parts between workstations. The cobot handles parts weighing between 2.5 kg and 3.5 kg at an estimated pace of 600-700 times per day. The worker performs quality control on the lifted workpieces. The quality control measures have expanded, as the cobot automated the lifting task.		

CS ID2	**SWEDEN**	**AI AND ROBOTIC SYSTEM**
One of the largest automation integrators in Sweden, the company examined for this case study is a supplier for a variety of automated solutions. By supplying customers with individualised, intelligent solutions, the company aims to increase efficiency and quality in the customers' production and logistics. The case study is based on their solution in a sawmill production line in which they employ a combination of robotic automation as well as an AI-based visual system. Along the production line,		

[6] See: https://data.oecd.org/entrepreneur/enterprises-by-business-size.htm

CS ID2	SWEDEN	AI AND ROBOTIC SYSTEM
wooden boards are undergoing a variety of transformation steps, including visual quality control measures. Unfit boards need to be removed from the production line, a step that previously included manual intervention from workers. The workers oversee the production and monitor the system's decision.		

CS ID3	GERMANY	AI AND COBOT
The presented company is a conglomerate focusing on a variety of sectors. It specialises in automation and digitisation in industry, infrastructure for buildings, decentralised energy systems, mobility solutions for rail and road traffic, and medical technology. This case study focuses on one branch of the company located in Germany, specialising in digital transformation. The branch produces parts for industrial switching technology, circuit breakers for industrial applications, infrastructure and buildings, across a variety of over 1,200 different products. They use both AI-based systems and cobots to automate a variety of tasks. The two presented are examples of the systems at their factory. Cobots are primarily used in slow-cycle assembly processes. The worker and cobot work on the same workpiece, where the cobot typically provides physical support by holding the workpiece. This allows workers to perform complex assembly tasks easier and without the strain of lifting the workpiece. Furthermore, the branch also uses autonomous guided vehicles (AGVs). They perform material delivery tasks and navigate the shop floor autonomously. They are also able to lift, load and unload themselves if needed. Workers can command them to retrieve material as they need it.		

CS ID4	GERMANY	AI AND COBOT
The presented company is a conglomerate focusing on a variety of sectors. It specialises in automation and digitisation in industry, infrastructure for buildings, decentralised energy systems, mobility solutions for rail and road traffic, and medical technology. This case study focuses on one branch of the company located in Germany, specialising in digital transformation. The branch produces parts for industrial switching technology, circuit breakers for industrial applications, infrastructure and buildings, across a variety of over 1,200 different products. They use both AI-based systems and cobots to automate a variety of tasks. The two presented are examples of the systems at their factory. The presented AI-based system is a computer vision system in product inspection. The AI is part of an automated optical test method using X-ray inspection for working parts that are not easily accessible for visual inspection. The AI analyses the X-ray images and determines whether the flag is a false positive or not. Should the AI classify it as a likely false positive, no further inspection is performed. The operator still performs the workpiece inspection, however, they now have a reduced workload, as the AI flags false positives early.		

CS ID5	PORTUGAL / GERMANY	COBOT
The company is an automotive supplier operating on a global scale and specialises in the field of drive and chassis technology. They were founded in Germany, however today they have manufacturing locations internationally. They provide customised integrated solutions for automobile manufacturers, mobility providers, and other companies with a focus on transportation and mobility. Next to cobots they also use AGVs in their manufacturing process. The presented case study includes a cobot solution implemented in a Portuguese manufacturing site. The cobot automates a sewing task for bags, which are needed for the car manufacturing process. The worker loads, secures and unloads to the cobot's workspace and uses the sewn bag pieces for final assembly. The workers also entered a new shift rotation system, as the cobot performs the sewing task faster, which frees up workers' time.		

CS ID6	USA	AI AND ROBOTIC SYSTEM
The presented company is a United States-based vehicular automation start-up that develops software and hardware to automate construction equipment, such as excavators. This automated excavation system adds autonomous robotic capabilities onto the existing heavy equipment. The underlying technology functions through a combination of GPS, cameras and AI. The entire system is made out of four main components: the external robotic system fitted to the excavator, a specialised operation software, robotic operation tools and a remote monitoring service. The system has the capability to operate fully autonomously, and the system allows the existing excavator to switch back to manual operation. At any time during the trenching process, the operator can switch from autonomous to remote control mode. In autonomous mode, the system uses input data from all its sensors, to dig trenches in the preassigned area. Via ongoing video feed analysis, the robotic excavator can also identify and react to obstacles it detects. This AI-based system classifies the obstacle and displays real-time warnings to the operator. The system automates a variety of tasks, with a scalable degree of automation. Operators still need to be able to perform all tasks related to trenching, but the system can support both their physical wellbeing and mental strain.		

CS ID7	DENMARK	AI AND ROBOTIC SYSTEM
The primary user of the presented technology is a Danish technology company with a focus on energy components. Together with a German AI company, they have created a hybrid system of a robotic arm and an advanced AI-based vision system that enables the robotic arm to detect workpieces and accurately pick them up from their delivery pallet and place them onto a storage pallet for further processing. This process was already partially automated before the AI-based vision system was introduced, however, the system improved the efficiency significantly. Subsequently, human intervention decreased, allowing workers to perform their primary tasks without reoccurring interruptions. In addition, as workers now do not need to manually adjust misplaced workpieces, they have a lightly reduced risk of minor injuries from handling sharp objects. This system primarily affected the company's delivery cycle. They were able to reduce night shifts for their workers, thanks to the system. The system was created in a collaborative effort with several other technology experts. This includes robotic integrators as well as the aforementioned German AI company. The Danish company developed the underlying vision system. They are a small company with fewer than 50 workers, specialised in 3D vision systems with customised AI solutions for their clients.		

CS ID8	GERMANY	AI
The government research institute reported on in this case study focuses on a wide variety of topics and research relating to OSH. One of their specialist research departments focuses on particulate hazardous substances such as nanomaterials. To research the effect of particulate hazardous substances and innovative materials, they use state-of-the-art equipment for aerosol measurement, particle analysis and imaging. A recent addition is an AI-based system to support researchers in determining the count of specific fibre material in a sample. They developed their system themselves. The imaging process can produce up to 700 images per cycle, in which only certain particles are relevant to the researchers. Automating the detection and analysis of particles in these images with an AI-based system makes it more efficient, decreases analysis time and reduces potential errors.		

CS ID9	GERMANY	AI
The oncological centre is part of a hospital in central Germany and was certified according to the guidelines of the German Society for Haematology and Oncology in 2011. As part of the larger municipal hospital, they follow its core values to provide the highest level of care, meet external structural and quality requirements, and work based on reliable scientific knowledge. They developed an AI-based system to support their doctors in colon cancer diagnostics. A colonoscopy is one of the most frequently performed forms of cancer preventive care in Germany. During a colonoscopy a colonoscope transmits images of the intestinal mucosa to a monitor. Here, the practitioner inspects the images for intestinal polyps, adenomas and early stages of cancer. The AI has an increased detection rate, particularly for small, flat or difficult-to-detect adenomas smaller than 5 mm. The AI can operate without delay and display suspicious areas live to the practitioner. However, final decision authority lies with the doctor. The system has the potential to decrease overall workload on hospital staff, as it increases the likelihood of cancer being detected in early stages. Early-stage diagnosis leads to earlier medical intervention with higher success rates, resulting in fewer severe cases in the hospital.		

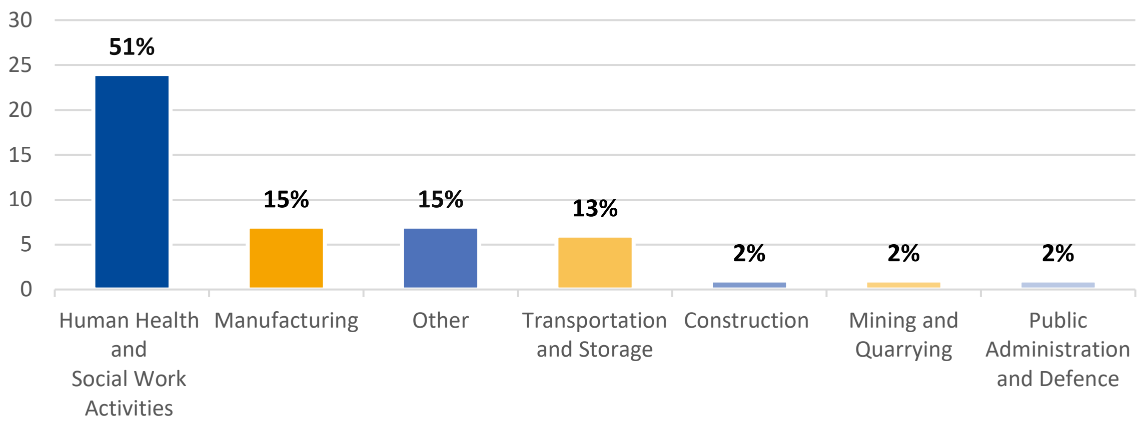
CS ID10	NORWAY	ROBOTIC SYSTEM
The Norwegian gas infrastructure company is an operator for integrated systems for transporting gas from the Norwegian continental region to other European countries and the United Kingdom. They operate pursuant to the Norwegian Petroleum Activities Act and in close collaboration and agreement with the gas transport system owners. This also includes maintenance of current and future developments of gas infrastructure. An integral part in fulfilling this mission is the maintenance of a reliable and safe gas transportation infrastructure. Specialists have previously performed the inspection process manually, by entering and inspecting gas tanks themselves. This work is both straining and dangerous; hence, they turned to robotic solutions to automate the task. They created a dual-robot solution to automate different parts of the inspection process. These two systems enabled them to remove inspectors from inside the gas tanks. The inspectors operate the robotic systems at the vessels, but they do not have to physically enter anymore. The intervention has not only drastically improved efficiency but more importantly also worker safety.		

CS ID11	NETHERLANDS	ROBOTIC SYSTEM
This Dutch technology developer focuses on agricultural machines related specifically to the tenure of milk cattle. Working in agriculture has historically been demanding physical labour.[7] Innovative technology offers a way to make working in this sector not only safer and more efficient for the animals involved but most importantly also for the farmers. The specific robotic system presented in this case study is an autonomously driving robot that specialises in manure clean-up. The robot autonomously drives through the stable and collects manure in its tank. Once it is full, it drives to a deposit station and empties its tank there. The robot can navigate the stables and cows independently but can also be controlled manually and remotely by the farm's staff. While the primary goal of developing this type of robot was to increase the hygiene standards in milk cattle stables, the company also sees how their technology can make farmers more independent and reduce their physical workload.		

3.1 Sectoral distribution of case studies

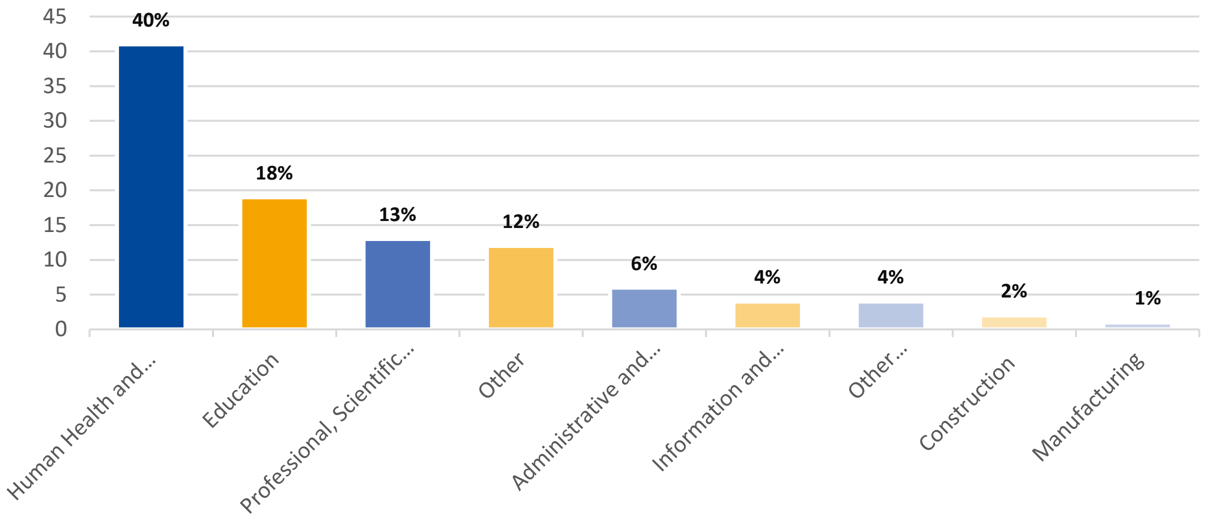
This section presents the sectoral distribution of the case studies, contextualised by the findings of desk research presented in previous EU-OSHA reports[8,9,10] as well as other research. The case studies present a representative part of all currently used advanced robotics and AI-based systems in Europe. Previous research has looked at the distribution of the automation of physical tasks (Figure 1) and cognitive tasks (Figure 2), covering both AI-based systems and advanced robotics.[11,12]

Figure 1: Automation of physical tasks NACE sector distribution according to scientific literature (percentage of literature referring to the respective sector)



[7] Jakob et al., 2021: Occupational health and safety in agriculture – A brief report on organization, legislation and support in selected European countries
[8] EU-OSHA, 2022: Advanced robotics, artificial intelligence and the automation of tasks: definitions, uses, policies and strategies and Occupational Safety and Health
[9] EU-OSHA, 2022: Advanced robotics and automation: implications for occupational safety and health
[10] EU-OSHA, 2022: Cognitive automation: implications for occupational safety and health
[11] EU-OSHA, 2022: Advanced robotics and automation: implications for occupational safety and health
[12] EU-OSHA, 2022: Cognitive automation: implications for occupational safety and health

Figure 2: Automation of cognitive tasks NACE sector distribution according to scientific literature (percentage of literature referring to the respective sector)



The sectoral distribution of robotic systems capable of directly interacting with humans in Europe can also be derived from the Third European Survey of Enterprises on New and Emerging Risks (ESENER 3).[13] Here the data shows a strong pervasiveness of robotic systems in the manufacturing sector (28%), followed by wholesale and retail trade; repair of motor vehicles and motorcycles (19%). Six per cent of the enterprises from the sectors human health and social work report using human–robot interaction (HRI). The lowest numbers of HRI applications are found in the sector electricity, gas, steam and air conditioning supply (0.2%).[14] According to current literature, human health and social work activities is the most researched category for physical and cognitive automation, followed by manufacturing for physical automation and education for cognitive automation.

The case studies reflect manufacturing as a dominant sector. However, 60% of case studies originate from other sectors, namely: wholesale and retail trade; repair of motor vehicles and motorcycles; construction; electricity, gas, steam and air conditioning supply; and professional, scientific and technical activities as well as human health and social work activities. It must be noted that many of these companies are large, international enterprises that provide a number of different services, branching into other sectors. The case studies are intended to include a diverse set of companies in different sectors. Nonetheless, they do reflect that some sectors already use more advanced robotics and AI-based systems than others. The discrepancy between the distribution of research interests and in-field applied technology can also be explained with the current state of technology. Systems in the human health and social work activities sector as well as the education sector are currently being developed and researched before they are introduced to the market. Tasks in these sectors are also often person-related and non-routine. These types of tasks are harder to (semi-)automate.

When interpreting the results of the case study analysis one has to be mindful that they represent a subset of all possible case studies and applications for advanced robotics and AI-based systems. Nevertheless, one can gain valuable insights from examining both their differences and similarities.

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[13] EU-OSHA, 2022: Third European Survey of Enterprises on New and Emerging Risks (ESENER 2019): Overview Report. How European workplaces manage safety and health

[14] Wischniewski et al., 2021: Results from the Third European Survey of Enterprises on New and Emerging Risks on Human-Robot Interaction

3.2 Description of technology

Throughout the case studies we see a number of different technologies being used to automate both physical and cognitive tasks. The detailed description of each individual technology can be found in the corresponding case studies. Here, we focus on providing an overview of the types of technology used and their general area of application. It becomes apparent that the same type of technology can be used to automate different tasks in very different environments.

Multi-axial single- or dual-arm robots (cobots)

Lightweight robotic systems with multiple axis and single or dual arms are among the most commonly used advanced robotics. They can be highly customised in their movement and can support considerable weight, while also performing precise motions. These systems can operate without significant additional safety barriers between human workers and robotic arms. Hence, they are frequently referred to as cobots, or collaborative robotic systems. While not every system described as a cobot necessarily meets the strictest scientific definition of a collaborative robotic system, they commonly share the traits that they interact at the workplace with a worker, without any additional barriers, and work towards a loosely shared goal. The term cobot can be applicable to systems in a multitude of sectors and environments.

Cobots are most commonly found in conventional automation environments that are accompanied by large IT infrastructures and serve the purpose to get high numbers of products as their output. Within these large-scale productions, product variations often require a modification of the assembly line. This process is very costly. However, the need for more customised products and more agile production grows. Instead of modifying an entire assembly line to meet those needs, smaller intentional intervention through technology and skilled human workforce can achieve this goal. Assisted by advanced robot systems, changing production requirements can be met.

In less heavily standardised environments, cobots typically assist in assembly or other applications, for example, part retrieval. Programming precision-based manipulation tasks for advanced robotics currently is difficult and creates high costs. However, repeated, physically supportive tasks seem more codifiable. While the robot often holds or positions a workpiece, the worker performs the precision task. In work systems where speed and accuracy are the primary automation criteria, it is unlikely that state-of-the-art collaborative robots will be as economically viable as fenced industrial robots[15]. A human and robot **cooperating** is the most frequently observed form of interaction in the case studies — the robot does the simple, repetitive part of the task. The human accomplishes the more precise tasks and takes advantage of their higher dexterity and cognitive understanding. Integrating a robotic system into a running production line raises the problem of standardisation. As the working environment becomes more standardised, as is, for example, the case in mass production scenarios compared to small-series production, cobots' flexibility, which is their main advantage, decreases. This is strongly linked to the degree of autonomy a worker has within the working systems. In most cases, a high level of standardisation is reversely related to the workers' freedom in how to perform a certain task and how or what assistive system to use. As the choice of use becomes less flexible, the added value of cobots with high flexibility decreases. Real **collaboration** between humans and robots, where both parties work on the same object at the same time, appears very rarely. As stated by the International Federation of Robotics (IFR), today we mostly see the interaction form of **co-existence** where human and robot share their workspace but do not operate on the same object at the same time or sequentially (IFR, 2020).

There are several third-party suppliers that produce these lightweight robotic systems. Most companies that use those systems buy them from such suppliers, however, there are also instances where companies develop their own systems. These companies are often already in the technology production sector, hence, they have the expertise and infrastructure to create their own customised solutions. In

[15] International Federation of Robotics -IFR. (2022). *Executive Summary World Robotics 2022 - Industrial Robots*. https://ifr.org/free-downloads

case of buying from a third party, it is most commonly the gripper of the robotic system that is individualised to perform its task.

AGVs, mobile robots

AGVs are an interesting case of modern technology. Some models are only capable of transporting items, as they do not have any external manipulators, however, there are those that can load and unload themselves autonomously. By this description, they can be classified as a cobot, or **mobile robot**. They are executing autonomous motion in an unfenced workspace with humans, supporting them in their task. They navigate their surroundings most often based on hardcoded but complex paths or based on a continuous sensor input. The integration of AI-based software could optimise the distribution of merchandise, so pathways for humans or robots within the warehouse, for example, to pick up the most popular purchased goods, are improved with a consequent time saving. Most often, they are not referred to as cobots, but as AGVs or mobile robots, and due to their specific nature, they can be utilised in almost any sector and work environment. Unlike the above-mentioned lightweight cobots, AGVs are defined by their task of moving (themselves and items) around. Hence, they form a distinct group within the advanced robotics, and that’s why they receive their own category.

Visual input processing AI-based system

While cobots always have a physical part, AI-based systems do not necessarily have one and consist of just software components. One type of repeatedly seen AI-based system in the case studies is a visual input processing system, which generates an output for the operator. These systems can be found in a number of work environments, be it from analysing medical scans to a video feed of a worksite to performing visual inspection and quality control in a production environment. Unsurprisingly, this type of visual analysis task is where AI shines. Before being employed for their tasks, these systems are trained on indexed datasets. Case studies repeatedly stress the importance of good training data, as they determine the quality of the final product. In the included case studies, the companies largely developed their AI-based systems themselves or hired a third party for a personalised product. While there are some programs that incorporate AI that can be commercially bought, the specific intended use for the algorithm currently encourages custom solutions.

While these systems are sometimes described as self-learning systems, it is important to be aware if this process happens, and when it takes place. The included AI-based systems that utilise self-learning algorithms are trained on data before in-field application, and the active training mode is not executed during normal operation. In some cases, the system is updated after some time to improve accuracy, however, not during runtime.

AI–robot hybrid systems

It is becoming increasingly common that the combination of AI with advanced robotic devices is used to increase the level of autonomy and functionalities of the system. However, it has to be noted that in a considerable number of advanced robotics it is not genuine AI-based software yet, but rather highly advanced traditionally programmed software. Whether or not AI is implemented within a robotic system is often not even noticeable to the end user. For example, object identification and grasping an identified object can be programmed without an AI-based backend. If traditional programming was executed well, the difference between both types of systems can be unobservable to the end user. However, as the usage of such systems increases, the robustness of performance, range of capabilities and a smoothness in actions will become noticeable and will likely further incentivise the inclusion of AI in advanced robotics. In case studies that integrate AI-based software into robotic hardware, we observe more elaborate moving behaviours, especially in unstructured environments or in natural language processing. However, these combined technologies are still at an early stage, and rarely found in in-field applications. When looking at current real-life case studies, they predominantly distinguish between AI-based software and robotic automation. Some hybrid cases are emerging; however, they are in the minority. A number of different advanced robotics capable of interacting with humans are addressed in scientific literature. They can be categorised according to their intended purpose as well as by distinct features like mobility.

3.3 Taxonomy-based categorisation

The integration of AI-based systems and advanced robotics may have significant positive impact for growth in productivity as well as for OSH. To categorise different types of technology, a taxonomy specific for important characteristics of AI-based systems and advanced robotics was developed. The taxonomy developed by EU-OSHA[16] (Figure 3) includes what type of backend and frontend is being used and the type of task performed, as well as which category it falls under (information-related, person-related or object-related). Examples of person-related tasks include teaching, care work and customer service, where work takes place through a social interaction between two (or more) actors. In this case, one of these actors is an AI-based system or a cobot. Second, information-related tasks involve processing data, such as software code generation, financial services and health monitoring. Third, object-related tasks commonly relate to a worker acting upon an object, part assembly, like driving a car, and making repairs.

The taxonomy distinguishes between routine and non-routine task characteristics as well as the degree of automation in the form of assistance or substitution. Finally, the taxonomy takes into account different OSH dimensions (physical, psychosocial and/or organisational) that are impacted by the technology. Each case study was analysed in the context of their categorisation in this taxonomy.

Figure 3: Taxonomy for AI-based systems and advanced robotics for the automation of tasks

The categorisation is based on the provided answers during the case studies' interviews. It also focuses on the primary technology described in the case studies. Some companies listed a number of

[16] EU-OSHA, 2022: Advanced robotics, artificial intelligence and the automation of tasks: definitions, uses, policies and strategies and Occupational Safety and Health

technologies (e.g. AGVs as well as robotic systems, with and without an AI-based backend), however, they were not further included beyond providing an overview of advanced automation present in the company. Table 2 provides an overview of each case study's categorisation along the taxonomy.

Table 2: Overview of taxonomy-based categorisation of the case studies

ID	Backend (Software)	Frontend (Device)	Type of task	Task characteristics	(semi-) automation of task	OSH dimension
1	Complex, not AI-based	Physical manipulation	Physical: Object-related	Routine	Substitution	Physical & Organisational
2	AI-based	Physical manipulation	Physical: Object-related	Routine	Substitution	Physical & Organisational
3	AI-based	No physical manipulation	Cognitive: Object-related	Routine	Assistance	Psychosocial
4	Complex, not AI-based	Physical manipulation	Physical: Object-related	Routine	Assistance	Physical & Psychosocial
5	Complex, not AI-based	Physical manipulation	Physical: Object-related	Routine	Substitution	Physical & Organisational
6	AI-based	Physical manipulation	Physical: Object-related	Routine	Assistance & Substitution	Physical
7	AI-based	Physical manipulation	Cognitive: Object-related	Routine	Substitution	Physical & Organisational
8	AI-based	No physical manipulation	Cognitive: Person-related	Routine	Assistance	Psychosocial
9	AI-based	No physical manipulation	Cognitive: Information-related	Routine	Assistance	Psychosocial
10	Complex, not AI-based	Physical manipulation	Physical: Object-related	Routine	Substitution	Physical & Organisational
11	Complex, not AI-based	Physical manipulation	Physical: Object-related	Routine	Substitution	Physical & Psychosocial

Out of the 11 case studies, six use an AI-based backend software, while the other five function on a complex but not AI-based software. The majority of systems, seven out of 11, used a frontend that is capable of performing physical manipulation through robotic automation. The remaining three, all AI-based systems, performed no physical manipulation. Closely mirroring this distribution are the type of tasks the system performs. Physical, object-related tasks are the most frequently automated tasks (seven out of 11), followed by two cognitive object-related tasks and two cognitive information-related tasks. All systems perform routine tasks. Regarding substitution of labour or assisting workers in their labour, six systems substitute, four assist, and one system is capable of different modes of operation, hence providing either assistance or substitution as needed. **Regarding the three OSH dimensions, companies most commonly list the physical impact of the system as the primary and most significant, followed by organisational changes. Psychosocial impact is named the least frequent.**

This overview provides an interesting contextualisation on the use of different advanced technologies, both in the realm of robotics and AI. When looking at the match of backend to frontend it becomes apparent that all possible combinations are present. This is an important observation to further break free from the notion that AI-based systems and robotics are two separable technologies. There are AI-based systems that automate the function of a robotic system as well as AI-based systems without any physical manipulation or frontend representation of their tasks. Similarly, there are robotic systems that operate on a complex but deterministic algorithm, without any AI involvement. Being aware especially of hybrid systems (AI and robotics in combination) is vital to understand the range of applications possible for these systems. It is also important for any integrator to know whether they are dealing with an AI-based backend or not. However, for the end user it is not always possible to determine in these hybrid systems if the software is AI-based or deterministic. Depending on the specific application of the system, workers should be informed of the exact type of technology they interact with.

Type of task is the most complex categorisation in the taxonomy. Physical and cognitive tasks do not always appear as binary, which is reflected in the taxonomy. Furthermore, both types can appear in the context of an information-, object- or person-related task. Some of these combinations are more frequent than others; physical object-related tasks and cognitive information-related tasks being two examples that occur frequently in literature,[17] while a physical information-related task presents a more niche case. Within the case studies this pattern is somewhat confirmed, with physical object-related tasks being the majority of automated tasks, especially in combination with a robotic frontend. Two case studies without physical representation perform cognitive information-related tasks. The two case studies in which AI-based systems are involved in object-related tasks but perform cognitive tasks are interesting examples. Case study seven (ID7) actively focuses on the underlying AI-based system, which enables a robotic arm to perform a sorting task. However, the AI is not used to enable the system's movement but rather inspection of the workpieces. The AI is used to determine position information of the workpieces so the robot can pick and position them accordingly. However, it is the movement of the workpiece that is the primary goal of the system, hence, it is object-related. Case study three (ID3) shows a similar case. The AI processes X-ray images for the quality control of a workpiece. So once again, while the system is analysing information, the transformation of this input is not the end goal of the work process. These two cases also highlight that most workplace tasks can be broken down into a number of subtasks with differing degrees of physical and cognitive qualities. To determine which category a system falls under, one should consider the end goal of a certain work process.

All systems perform routine tasks. In the context of the presented taxonomy, task characterisation regarding routine and non-routine is a crucial element in terms of its automation potential.[18] Present AI-

[17] EU-OSHA – European Agency for Safety and Health at Work, Advanced robotics, artificial intelligence and the automation of tasks: definitions, uses, policies and strategies and Occupational Safety and Health, 2022a. Available at: https://osha.europa.eu/en/publications/advanced-robotics-artificial-intelligence-and-automation-tasks-definitions-uses-policies-and-strategies-and-occupational-safety-and-health

[18] EU-OSHA, 2022: Advanced robotics, artificial intelligence and the automation of tasks: definitions, uses, policies and strategies and Occupational Safety and Health

based systems still have difficulties performing non-routine or non-standardised tasks. **This also supports the outlook that jobs with more codifiable tasks will be more rapidly displaced by the advancing technology.** While AI-based systems can be used to cover a wide array of different tasks (e.g. case study ID7 is considering expanding their AI-based systems' capabilities to around 2,000 different products), for many systems it is also a consideration of effort versus pay-off when it comes to deciding which tasks to automate. It is simply more effective and profitable in most cases to automate routine tasks first, before tackling the more complex non-routine tasks. In addition, tasks that are non-routine might be difficult to solve for a software system, but comparably simple for a human worker.

Within the case studies there is a mixture of systems substituting human labour and assisting workers. Once again it is important to consider the larger task context for this categorisation. A robotic system, like in case study (ID1), which lifts workpieces so the worker can perform an inspection and final assembly tasks is theoretically substituting the task of lifting for the worker. However, it is assisting the worker in their overall task. So, this categorisation should be seen from a human-centred perspective, as well as take the larger task context into consideration. Case study (ID6) presents an interesting system that is capable of both fully substituting a worker's input in the tasks as well as assisting them when they perform it. This gives the worker significant control over the technology and the degree to which it is involved in the work process. Furthermore, when it comes to automation with advanced technological systems, case study ID6 highlights the role of environment. This case study demonstrates the use of AI-based systems as well as external robotic add-ons, from existing excavators to automate trenching. This process can be performed fully autonomously, by the system, on certain construction sites (e.g. fields with no pre-existing infrastructure in the ground), however, there is still a need for human intervention and control in more complex trenching locations (e.g. urbanised areas with underground water supply, pipes or telephone cables). By giving the user the flexibility to adjust the degree of automation as needed, the systems can potentially be used on more work sites. **Creating systems with flexibility can be a first step towards automating more non-routine tasks as well.** Systems that assist workers, on the other hand, often automate the most repetitive or strenuous part of the task. This enables workers to either focus more on the cognitively challenging, creative tasks related to the physical automation or simply perform their tasks faster and more efficiently.

The three OSH dimensions (physical, psychosocial and organisational) can be impacted by every type of system. When asked, most companies name the physical component of OSH to be the most frequent and strongest affected. This is understandable, as many systems automate physical tasks. Organisational changes in relation to OSH are the next most frequently named group. This is not entirely separable from many case studies' efforts towards automation in their work sites. Advanced robotics and AI-based systems can incite organisational changes that benefit OSH. One example of this can be found in case study ID7, where the introduction of the system allowed them to reduce night shifts, and in case study (ID5), where the technology allowed a restructuring of work cycles to balance workers' job demands throughout the day. The least frequently named category is psychosocial factors. However, one can observe an interesting discrepancy between the categorisation companies provided and the factors they name once they talk about the OSH challenges and opportunities they have experienced with the technology. Most of them name at least one type of psychosocial OSH factor that is affected by the introduction of the technology. These can be positive, like an increase of social interaction (as opposed to social isolation) and a reduced cognitive load, or negative, like fear of job loss or mistrust towards the system. One possible explanation for this mismatch in the reporting is the prevalence of these topics in companies' culture. Especially with robotic systems, considering the physical impact they can have on OSH, it is mandatory to carry out risk assessments. Also, this could possibly be attributed to the complexity of psychosocial factors associated with the use of AI and the lack of understanding of such factors from all relative interviewed stakeholders. Integrating the system at a workplace can already be considered an organisational step to improve OSH, hence, expanding these changes to a larger scale by introducing further restructuring follows the same line of reasoning. However, knowing that these systems can have noticeable positive or negative effects on psychosocial OSH factors is just as important as other possible impacts, for companies. Not only can psychosocial factors like stress or fear of job loss be detrimental to workers' health, but factors like mismatched trust can also increase physical risks from misuse of the system.[19] Similarly, overlooking possible positive psychosocial effects, and therefore not focusing on enhancing them, would be a missed opportunity to improve OSH. Both companies that already have AI-based or advanced robotics and those that plan on integrating them in the future should consider how the technology will affect OSH in all three facets, in order to determine the potential for positive change and avoid or counteract as many negative effects as possible.

Overall, the case studies developed for the current study involve a diverse portfolio of technology and task combinations. However, not every possible combination has been covered. This is, as mentioned above, partially due to the fact that some combinations are more common than others. When consulting literature regarding the automation of tasks through AI-based or advanced robotics, however, we can see that there is an even more diverse range of technologies and tasks combinations being researched and possibly used in the future.[20] Especially person-related tasks in the realm of healthcare are among the most researched ones. Many of these systems are not yet used in workplaces. Nevertheless, once these systems become market ready, there can be valuable insights gained from including them in future case studies.

3.3.1 Types of task automation and job content

The following section presents the findings and comparison regarding the effects that automation of tasks through advanced robotics or AI-based systems can have on workers and their surroundings. Specifically, this section looks at the impact the automation has had on their job content and work routine. As described in the taxonomy, tasks can be person-related, information-related or object-related, based on the object of work according to the focus programme 'Occupational Safety & Health in the Digital World of Work', established by the Federal Institute of Occupational Health and Safety in Germany.[21] In a previous report by EU OSHA,[22] the type distribution of AI-based systems in the reviewed scientific literature was assessed. Information- and person-related tasks are dominantly featured in literature, while object-related tasks form the smallest group. This report did not include robotic systems.

Figure 4: Task type distribution according to scientific literature

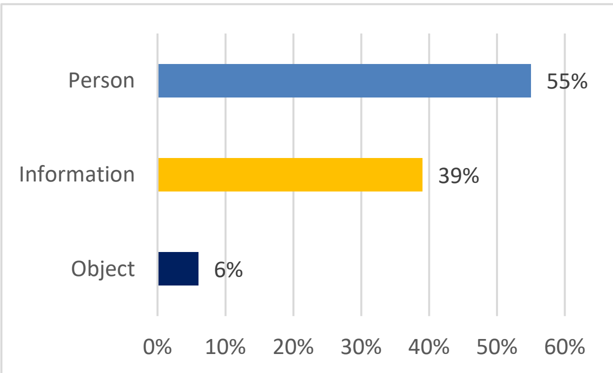
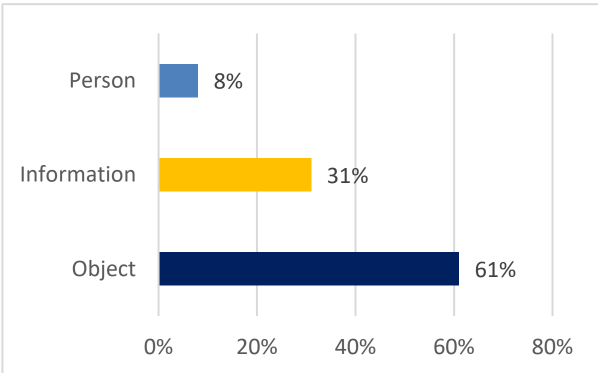


Figure 5: Task type distribution in the case studies



Compared to this, the tasks automation presented in the case studies show a differing distribution. Here AI-based system, robotic systems and hybrid systems are included. While the number of information-related tasks that are automated by these systems stays comparable, there is a steep difference when it comes to object- and person-related tasks. The companies in these case studies automate no person-related task. Instead, object-related automation dominates. There are two possible reasons for the difference in distribution. Firstly, the case studies represent a smaller sample than the reviewed literature. Papers that include person-related tasks are primarily in the educational or medical sector. During the selection of case studies for this study, there was an active effort made to identify and include current

[19] Hancock et al., 2020: Evolving trust in robots: Specification through sequential and comparative meta-analyses
[20] EU-OSHA, 2022: Cognitive automation: implications for occupational safety and health.
[21] Tegtmeier et al., 2019: Sicherheit und Gesundheit in der digitalen Arbeitswelt
[22] EU-OSHA, 2022: Advanced robotics and automation: implications for occupational safety and health.

case studies in those sectors that automate person-related tasks. However, due to the rarity of these systems being used in the field today, no case study looking at person-related tasks could be included. There are instances of cobots, for example, in Japan, automating physical lifting tasks in nursing homes, however, these case studies are comparably rare.

The difference in distribution highlights that while a wide range of task types is being researched, when it comes to actual application in the workplace, some of these technologies are not yet market-ready or only starting to be used by a few companies around the globe. Tasks that involve other humans also have the potential to be more complex than, for example, an object-related pick and place task, or an information-related image analysis. Hence, it is more difficult to create a system that is robust enough while still being effective. **The majority of task automation currently takes place in relation to object-related and information-related tasks, as these types of tasks are more easily codifiable.** However, this difference also indicates that there are active efforts being made to improve and research systems that automate person-related tasks, indicating a possible future rise in popularity of these systems.

Depending on what type of task is automated and especially how it is automated, workers might experience a shift in their job content. This change differs from case study to case study, as the automation of each individual task impacts not only the task itself but also tasks leading up to it and follow-up tasks. Table 3 provides an overview of the tasks automated by the case studies, to which degree they have changed the job content of the worker at that workstation and which further tasks were impacted by the change.

Table 3: Degree of change in job content, based on the task automation through an AI-based system or advanced robotics

CS ID	Task description	Change in job content	Change in routine	Further tasks impacted
1	Lifting medium weight parts for quality inspection	Little to no change	Little to no change	Shift towards cognitive task
2	Visual quality control on lumber, and physical removal of unfit lumber from production	Complete change	Complete change	New type of job created
3	Holding lightweight workpieces for assembly	Medium change	Little to no change	Subsequent and preparation tasks are unchanged for the worker
4	Determining X-ray-based error detection to be a false positive for further inspection	Little to no change	Little to no change	Workload reduction
5	Sewing bag parts	Medium change	Complete change	Change in workday structure based on the machine
6	Automating trenching	Medium change	Significant change	Workers have the option to use the system, but still need to know everything manually

CS ID	Task description	Change in job content	Change in routine	Further tasks impacted
7	Depalletising and palletising of workpieces for further assembly	Little to no change	Significant change	Subsequent and preparation tasks are unchanged for the worker
8	Image analysis for hazardous material	Little to no change	Little to no change	Subsequent and preparation tasks are unchanged for the worker
9	Real-time video footage analysis of a colonoscopy for cancer	Little to no change	Little to no change	Subsequent and preparation tasks are unchanged for the worker
10	Gas vessel inspection	Significant change	Complete change	Change of entire pre- and post-inspection process
11	Manure removal	Little to no change	Little to no change	New scheduling tasks added

Little to no change: Job content remained largely unchanged. Some new skills and knowledge needed to be acquired to work with the advanced robotics or AI-based system.

Medium change: Job content is still recognisable to the content before the automation. The core task has not changed significantly, however, relating tasks have. This can include the addition of new preparation or subsequent tasks, or the addition of technology-specific tasks, like maintenance. All major skills for the original tasks need to be preserved.

Significant change: The automation has impacted the job on a structural level. New skills had to be acquired to perform the job. Workers' routine and environment have been shaped by the technology.

Complete change: The automation has changed the work environment beyond the point of comparison. Workers might still need knowledge of the original task, however, the new tasks that arose from the automation have potentially created new jobs that do not require that knowledge.

The impact the automation has had on workers' job content and routine differs for each case study. As we can see, there are a few systems that have not changed the job content significantly. Those are typically systems that assist workers during a larger task (e.g. lifting a workpiece, so the worker can perform an inspection). These types of automation also impact a worker's routine to a lesser extent. While there can be concerns that assistive systems increase the rate with which workers have to perform their primary tasks, according to the case studies, this is not what has happened. Rather, they spend more time on the primary tasks (e.g. performing a more thorough inspection) or use the remaining time to attend to other, secondary tasks. This pattern is largely mirrored by how a worker's routine is impacted as well. However, there are some noticeable exceptions to this. Three case studies identified complete or significant changes to the job content and workers' routines. Case study (ID2) describes a lumber mill that uses robotic automation. This case study is special in the sense that it was newly built. So, one can argue, a change in job content or routine happened at a completely new workplace. However, compared to other workers in the industry, should they take a job at said sawmill, their job content and routine would no longer resemble their previous tasks. Case study ID5 includes a cobot that automates sewing of bags. The job content is affected to a lesser extent than the workers' routine. The workers no longer perform the sewing tasks previously required and must perform new tasks that involve using the cobot. However, most of their other job content remains the same. However, shop floor workers' routines have significantly changed, as the company used the automation as a starting point to do so by introducing a rotational system. Workers previously worked at all the stations they work on now, but in a daily or weekly rotation. Now they rotate workstations during the day.

Finally, case study (ID10) identified a significant change in job content as well as in the workers' routine. The change in job content is explained because entire preparation steps for the gas vessel inspections have become unnecessary due to the robotic system. The content of the inspection itself did not change, but as they are now both faster and physically removed from the workplace, their routine has changed noticeably.

This view on the automation of tasks through advanced robotics and AI-based systems highlights that the systems do not have to be disruptive to the workers' routines, nor do they always change the job content significantly. In cases where both are strongly impacted, it was often the result of larger, partially OSH-oriented, restructuring efforts of the company. However, most systems are integrated into the workers' routines.

Another interesting aspect to examine is the remaining job content after automation. Many of these systems help in automating 3D (dirty, dull and dangerous) jobs. When looking at how the workers' job content has changed, including what kind of tasks workers perform instead of the tasks that have been automated, most companies have similar answers. In the long run, they aim to move workers towards performing more creative, cognitively involved and/or challenging work. In case studies where there was little to no change in job content, the most common new tasks that workers faced were related to operating and maintaining the technology that had automated tasks (though there are cases where this job is performed only by specialists), performing minor secondary tasks, or supervising and inspecting the system's output. The movement towards more creative, cognitively involved or challenging tasks in most companies is ongoing, as workers often need to receive specialised training to be assigned these types of new tasks. However, most case studies see this as the general direction their company is taking with their workers: **less dirty, dull and dangerous job content, and more creative, challenging and cognitive work**.

4 Implementation process

A key factor for successful integration of technology into a new working environment is the implementation process. Several factors, such as the identification of objectives and goals prior to implementing the technology, design decisions and participation, worker involvement and training, as well as the inclusion of guidelines or legislation, can influence it. In addition to these, one of the most important steps is the assessment of whether the intended goals have been reached, documentation of what challenges were faced, and finally how these lessons influence future company plans regarding the implementation of either new systems or more of those already implemented.

4.1 Motivators and goals for the implementation of advanced robotics and AI-based systems

Setting goals prior to implementing a technology can help quantify the success of implementation, and also inform what kind of technology is needed to reach them. In many cases, goals and motivators exist alongside each other. Often, a motivator is named as a work-related situation that has the potential for improvement (e.g. increased production, more ergonomic workplaces), and the goal is defined as changing this state for the better. Generally speaking, there are reoccurring motivators and goals among the case studies. The three major groups were organisational goals, economic goals and OSH goals.

4.1.1 Organisational

For many companies, these systems were the first of their kind to be introduced into their company. Hence, one of the primary goals for some was to learn more about the technology. This included understanding the scope of usage, testing the system for possible benefits and risks, and gauging its safety impact, as well as to learn about relevant regulations and current national and European laws regarding advanced robotics and AI-based systems.

However, these systems can also be introduced with the goal to change certain company structures. Case study ID7, for example, introduced their AI-based robotic system with the explicit goal to reduce night shift work for their staff. As the systems are capable of changing production cycles and the timing that human intervention is needed, companies can restructure their workplaces to either be more efficient or to reach other goals.

Another organisational incentive to introduce advanced robotics or AI-based systems that was named is to make a company/sector more attractive for future workers. Many companies struggle with attracting young and qualified workers, so using innovative technologies is described as one tool to make these workplaces attractive again.

One organisational subgoal that should be highlighted is the requirement for companies to upskill their workers as part of the automation process. They formulate the goal to prepare their workforce for the future of work and to enrich their company staff with a technology-focused and innovative mindset.

4.1.2 Economic

Economic reasons are also a significant motivator for integrating advanced robotics and AI-based systems into workplaces. This expressed itself in several goals. An increase in production, cost reduction, increased flexibility of production and increased product range as well as the ability to produce in smaller batch sizes with greater variation motivated the change towards a more heavily automated production. Having highly skilled workers spend their time performing high-value tasks, and spend less time on low-value tasks, also falls under economic motivators. What can also be included in this category is the wish for increased quality in their output. This is not limited to the realm of production but can also apply to other tasks. Case study (ID8) introduced the AI-based system to increase their quality of care for cancer patients by providing more accurate screenings. **This motivator is not always linked to financial gain for a company or organisation, as improvement of quality can also manifest in non-monetary benefits, like a better reputation or better patient care.**

4.1.3 OSH

Within all case studies there is the goal that automation through advanced robotics or an AI-based system will benefit OSH and especially the physical and psychosocial wellbeing of workers. Measures taken to automate physical tasks are primarily expected to reduce physical strain on the worker, leading to possible positive health benefits in the future, as well as an overall more ergonomic workplace. Other benefits the companies expect are a reduced risk of injury, both imminent and long-term due to strain, as well as accident reduction. OSH benefits that are often targeted with the implementation of systems that automate cognitive tasks are a reduction of monotonous, dull work, reducing the time workers spend in extreme concentration and boredom. **Overall, when it comes to the automation of tasks through advanced robotics or AI-based systems, the goal is to reduce unnecessary workload and make the workplace more ergonomic.**

4.1.4 Success rate

When looking at the aforementioned goals and motivators, it has to be noted that most companies had a combination of organisational, economic and OSH goals. However, while not every organisation reports on goals for the technology to incite organisational changes or to have economic impact, each one reports the improvement of OSH for their workforce to some degree. This coincides with the expectation for any automation to be an improvement at the workplace that everyone effected by it can benefit from in some way.

Most companies have been using these systems for a comparatively short time. The majority were installed or developed within the last five years. While some companies already had extensive experience with these types of systems before they installed the technology described in the workplace, for others it is a novel system. **Given the relatively short time frame, some effects and therefore the knowledge if a goal has been reached cannot be judged** accurately. One example of this is the impact on the development of long-term strain injuries. Other goals, however, like the reduction of immediate cognitive or physical workload, can already be judged. Concerning these short-term goals, the case studies report overall success.

4.1.5 Future implementation

As the case studies report, the implementation of these systems is considered to be successful since they reached the intended goals (as far as they can be assessed at this point in time), and they also report plans for future automation. The degree of future plans depends on the current state of automation in the company and the scope future developments can take. Several companies report they intend to introduce more of the same systems or similar. Others report that they intend to expand on the abilities their current system has. Case study (ID9) reports that the company wants to expand the AI-based system's ability to not only detect certain fibres but also to analyse what type of elemental make-up the material has. Case studies ID3 and (ID4) have a history of continuous automation in their workplaces and will continue to do so. Beyond production automation, human resources are looked at in terms of software solutions to automate and make the process fairer. The company presented in case study ID10 has started to offer their dual-robot solution to other gas infrastructure sites. Case study ID7 aims to make the technology usable for all their international factories. Case study ID8 provides a rough estimation that within 10 years most medical practitioners will use some form of AI-based system, both in hospitals and local doctors' offices. This development is mirrored by case study (ID11), which also sees the agricultural sector undergoing significant robotic and AI-based automation in the coming years.

All case studies indicate that the automation of tasks through advanced robotics and AI-based systems will continue in their sector. This result is in and of itself not surprising, for two reasons. Firstly, a subset of the case studies are technology developers' themselves (i.e. ID3, ID4, ID6, ID7 and ID11). Part of their business model is the development of advanced robotics and AI-based systems. However, most of them are also active users of this technology. Secondly, the automation of tasks through innovative technology has been an ongoing development in the world of work ever since the industrial revolution. Advanced robotics and AI-based systems are the continuation of this legacy. However, advanced robotics and AI-based systems offer new and unique solutions to the challenges of task automation. By being more flexible and autonomous than any other type of technology before, they can automate tasks previously too complex for machines, but dull, dangerous or dirty for humans. This modern technology can not only increase the efficiency of work but also increasingly benefit OSH, giving companies a double incentive to use it. This collective intent to introduce more advanced robotics and AI-based systems into workplaces further highlights the importance of research regarding their impact on OSH.

4.2 Implementation of advanced robotics and AI-based systems

4.2.1 Implementation steps

When it comes to the steps needed to implement a new technology, company size and complexity matters as well as the expected extent of the automation. Is it a new development, a further development or an adaptation of an existing infrastructure? In large companies, there is typically a formal process involved to implement new technologies. In smaller, or even family-owned businesses, the process can be less structured or less hierarchical. Most implementations in large companies start with a specialised team looking for automation potential in the company, however, in some cases the impulse can also come from within the workforce (ID3 and ID4). Depending on these factors, a project team is created, with a project planner, technical engineers, advisory security and safety engineers, and, in some cases, workers on site are involved as well.

In larger companies, which have workers councils, worker representatives are typically involved in the implementation process (e.g. ID3, ID4 and ID7). These teams develop a concept based on that initial impulse. The concept is presented to the project planning committee and upon agreement, a construction approval is given. A risk and safety assessment is then carried out, and cost proposals are obtained. In cases where the system has to fit into a pre-existing production line, initial test set-ups and preliminary factory acceptance testing are typically carried out. During these initial tests, future operators should already be involved and asked for their feedback on the system, including OSH concerns. **Considering OSH during the implementation, as well as consideration for the inclusion of these new systems into the OSH management system in the early stages of development, is not only important for successful implementation, but even more so for long-term operation.** This reduces the need for revision in the later process, and potentially reduces any initial risk the workers would be exposed to. When testing is complete, the system is set up on site and a real-time functionality test is carried out in which the system is tested under real conditions. During or before the actual implementation, operator training is carried out. Should any relevant revision happen, or change in functionality (this applies to both robotic and AI-based systems), the case studies report that typically the workers are informed prior to the change. Should the revisions be major, or impact how a worker uses the system, additional information is provided up to additional training sessions being arranged.

In other cases, the implementation process can be less formal. For case study ID9 the impulse to buy the AI came from the oncological centre's department head, and they had to obtain financial approval from the hospital administration. The provider installed the system and workers received the mandatory training. The process was rather quick. In case study ID8, they developed their system as part of an ongoing project, for their own use, hence the process was even less formal. Case study ID11 describes that their agricultural robots are typically bought from family-run farms, where the decision process is less formal than in other companies.

The point at which workers are getting involved in the process is equally diverse. As mentioned above in case studies (ID3) and (ID4), the impulse can come from within the workforce. Case studies (ID2), (ID7), (ID8) and (ID10) were actively involved in the creation and design of their final technology, while case study (ID1) adjusted a pre-existing system to their needs. While it is advisable to involve workers early in the implementation process, possibly even in the development process, this is not always possible. There is a significant difference in worker involvement between case studies where the technology was developed by the company itself (or in close collaboration with another company), like in case studies (ID3), (ID4), (ID6), (ID7) and (ID10), and when the technology was bought from a third-party provider and simply installed at the workplace, like in case studies (ID6) and (ID11). While it is not always possible to involve workers in the design of the technology that they will be using, they can still be involved early in the process. Informing workers sufficiently prior to the implementation can improve acceptance, even if they did not actively contribute to the technology.

The case studies illustrate that the steps taken in a successful implementation differ highly on a case-by- case basis. However, there is a tendency that when workers are involved early in the implementation process, companies face fewer difficulties in the long run.

4.2.2 Standards and regulations

The standards and regulations consulted by the case studies can be largely separated into those concerning AI-based systems and those focusing on robotics. To ensure proper workplace safety, the companies commonly adhered to several regulations and standards, both national and EU-based. It is important to know that this list is based on the answers the interviews for the development of the case studies provided. Hence, it is not an exhaustive list of all possibly applicable standards and regulations for the implementation of advanced robotics or AI-based systems.

Interviewees for the European case studies that integrate robotic systems discussed their consultation of International Standards Organisation (ISO) technical specification ISO/TS 15066 as well as robot-related standards like ISO 10218-2 and ISO 10218-1. In addition, they frequently referred to the European Machinery Directive 2006/42/EC.

Regarding national legislation, there are several types applying in most countries. However, companies often consult recommendations from several stakeholders. German case studies using AI report the importance of the DSGVO (German general data protection regulation), German IT baseline protection (IT-Grundschutz) and the letters from Digitalcourage. For the Swedish case study, the Swedish Work Environment Authority (SWEA) guidelines on the lumber and sawmill industry were considered. The Norwegian company operates under the Norwegian Petroleum Activities Act. The United States case study consulted American OSHA guidance as well as the American National Standards Institute (ANSI).

In addition to external **standards and regulations, most companies have internal quality and safety standards that they enforce**. **Most case studies also report consulting with universities or reading up on other case study reports applicable to them to keep up to date with current technological and legislative developments.**

4.3 Difficulties and challenges during the implementation

It is not uncommon that companies, institutions and organisations that plan to implement a new technological system encounter difficulties and challenges during the process. In the early 2000s, the estimation was made 'that up to 70% of new programs – from re-engineering, installing new technology to changing culture fail'.[23] Absolute numbers on the current success rate are difficult to find. However, based on the interviews conducted in companies, which have successfully implemented innovative systems like cobots or AI-based applications, the process is by no means guaranteed to succeed. The encountered difficulties and challenges typically belong to one of three categories: technology-related, human-related or organisational. Technology-related contains both difficulties with software and hardware and with availability of the technology. Human-related challenges can arise from workforce resistance to the implementation or the distribution of technological skill in the company, and organisational covers factors like adjustments that needed to be made on a structural level, problems arising during the planning process and financial considerations.

4.3.1 Technology-related factors

The type of technology-related challenges that arise highly depend on the type of system implemented at the workplace. The goal of most companies is to find the most efficient and best-suited technology for the task they want to automate. Here lies one of the frequently encountered challenges. While there are a number of systems on the market from third-party suppliers and especially regarding robotic systems there are options to customise them to one's specific needs, it can still happen that companies do not find a system suitable for their work environment. Or, related to this is that the available systems would incite changes in the work environment that are not desired by the company (e.g. increased noise level, or added significant costs).

Another technology-related difficulty is matching the new system to pre-existing production lines. Case study (ID6) reports that the installation of their technology on old excavators takes significantly longer than on newer models, and case study (ID1) reports that aligning the new technology, while considering present safety regulations, with the existing production line posed a challenge for their technical engineers. Similarly, the interviewees of case study (ID11) reported challenges with installing their robotic systems in stables that were constructed before robotic systems were ever capable of autonomous navigation. This can lead to an undesirable trade-off situation. To make the technology suit its surroundings, those surroundings have to undergo significant changes and upgrades themselves, which is costly. The other option is to fit the new technology to the capabilities of the pre-existing system, potentially reducing its efficiency. Case study ID2 illustrates that in certain cases, neither option is sufficient, and that the construction of a new, modernised production site can be more beneficial in the long run, in comparison to upgrading pre-existing production lines piece by piece.

It can also be a challenge to match the available technology to the task needed. Case study ID1 demonstrates that their current cobots have a maximum load of 15 kg and certain tasks require more strength. Without their risk assessment, the interviewees came to the conclusion that it would pose a

[23] Washington & Hacker, 2005: Why change fails: Knowledge counts

significantly higher risk than the 15 kg payload cobot. This makes the implementation of cobots not a viable option for certain workplaces in their company, even if a cobot would be well suited at that workstation.

A challenge for primarily AI-driven applications is typically the availability and quality of training data. Case studies that develop their program in-house often only have limited training data. This can be both a challenge and an advantage. Creating their own training data allows them to set high quality standards and implement their own screening methods for bias detection, like case study (ID9) did. On the other hand, this might also severely limit the quantity of available data to train the system on. However, this is a problem assumed to reduce over time, as companies gather more data and start to optimise their system.

4.3.2 Human-related

The automation of tasks through advanced robotics and AI-based systems is often associated with **resistance from the workforce, rooted in a fear of being replaced by technology**. Hence, it would be expected to find this worker resistance in the case studies. However, only two (ID5 and ID7) report that this phenomenon expressed itself to a degree that the company needed to take action. In case study (ID5), the resistance was rooted in the fear for physical safety, as workers did not fully understand the system and its safety features in the beginning. This was an entirely new technology to the workers. Their initial scepticism could be resolved by the company providing additional information on the safety of the technology, and also by workers experiencing first-hand that the system is safe.

Noticeably, there were no cases where a primarily AI-based system (like ID4, ID8 and ID9) encountered difficulties or challenges that were related to the workforce. One of them developed the system themselves, in a small team, hence, everyone contributed in some way to the development of the system. Another described a strong mindset of innovation among the workforce and the active interest to test out new technology. Both factors possibly contributed to the absence of human-related difficulties. Another possible explanation for this is that these systems tend to be less noticeable during everyday work. While a robotic system is permanently visible to the worker who interacts with it, an AI-based system that does not have a physical representation, like in case study (ID9), might not present visually differently from a classic non-AI-based algorithm. This could make it somewhat easier to both get used to the system and forget that it is AI-based, hence, not triggering any negative associations with AI-based systems.

Overall, **human-related difficulties and challenges were the rarest type of difficulty to be named across case studies**. This does not mean that they are to be neglected when implementing a robotic or AI-based system. The lack of these company internal problems can also be rooted in the sample that is included. Most case studies consider themselves innovative companies with a technology-forward mindset in their work staff. Case studies (ID3) and (ID4) actively encourage their workers to bring forward new ideas for automation and process optimisation. It is likely that people who work for these types of companies have an open mindset and interest towards technological innovation as well, which makes them less likely to challenge the implementation.

4.3.3 Organisational

The most frequently encountered difficulties and challenges can all be described as organisational. This includes financial and legal aspects of the implementation.

The mismatch between current legislation and the technologies' abilities is named by a number of case studies. Safety regulations and requirements were a frequent issue. In case study (ID1), the cobot needed to be slowed down from its maximum capacity to comply with safety regulations, as speed and force checks exceeded the limits set by the current regulations. The case study notes that initially the system was assessed to be safe to work with, at the original speed. These measures diminished the cost efficiency of the system. Case study (ID4) describes a similar problem, with the technical specifications making some installations inefficient, describing the additional measures as leading to an increase in costs.

Within the AI-based systems that are bought from third-party suppliers, there is less of a cost increase during the implementation process, but rather **a cost barrier**. While the benefits of these systems are known to many potential users, they are currently being sold at prices that prohibit smaller companies, or freelancers, like doctors with their own practitioner's office, from buying the systems. While this is not a challenge faced during the implementation process, it is a factor resulting in the technology being used less, despite the wish to use it more.

Another challenge encountered by people within the case studies was related to the initial research phase. There is a lack of available European-centric examples, good practices and case studies for companies to consult. Those that were accessible were often based in Asia, therefore reducing their transferability to the European market significantly. This coincides with the relative lack of experience with working with these systems as a whole. Most case studies express the wish to learn from others and share their experiences, however, at the current time, there are only very few options to connect and share experiences.

Some case studies also face organisational issues regarding the implementation time frame. It was perceived as a challenge to complete all steps of the implementation process, for example, technology selection, risk assessment, testing phase, operator training and so on, while keeping production going. **Case study (ID1) demonstrated that including a cobot in production was more time-intensive than a fully automated robotic cell, partially due to the extensive safety standards and testing.** The interviewees within this case study highlighted that safety and training of the workers must not be compromised to speed the process up, but, rather, there should be more consideration by project management when it comes to these technologies. However, case study (ID1) also showed that this increased time and effort has resulted in the decision that some workstations should not just have a cobot but rather be turned into a fully fenced robotic cell.

4.3.4 Summary of the difficulties and challenges

All case studies show that the implementation of a new type of technology will bring unique challenges to be overcome. Based on the interviewed companies, we do see a different distribution of the type of difficulties and challenges encountered between companies that implemented primarily robotics solutions for the automation of physical tasks and those that implemented AI-based systems that are not involved in the performance of physical tasks.

Generally speaking, those who implemented AI-based systems encountered fewer problems. The challenges that typically have to be overcome with these are primarily dependent on how the system is developed. In-house-developed systems present the challenge of gathering enough high-quality data to train the systems and simultaneously ensure that the system operates as free of bias as possible. In case study (ID8), interviewees continuously stressed the importance of having high-quality training data for high-quality output. Another problem that was encountered with AI-based systems used for the automation of cognitive tasks is associated with those who buy the system from a third-party supplier. Currently, many of these systems are considered expensive, to the point that even though they could benefit OSH as well as other factors (like cancer prevention in ID9), it is simply unfeasible for some potential end users to acquire the technology.

Both challenges can potentially decrease over time. New technology has historically reduced in purchasing price as time went on and competition increased. Hence, it is permissible to assume that as more companies develop AI-based systems, their general price will decrease. However, regarding the problem of bias-free training data, the development is harder to foresee. Most of these systems are used for highly specialised tasks, hence the training data will not increase as quickly. Interviewees in case study (ID8) pointed out that they currently are the only lab performing their kind of image analysis, while in case study (ID7), the AI was trained to identify a single type of product in a highly specialised position. Accumulating high-quality training data will remain a challenge for AI-based systems. It remains paramount that the training data are held to a high standard, as undetected bias can have negative consequences, not only for OSH but other factors too, depending on the application. One of the most named examples for this is AI applications in human resources with undetected gender or racial biases.

Challenges were also reported by interviewees related to systems for the automation of physical tasks with or without the involvement of AI. While availability of a suitable system was a problem for some, users in most of the case studies either created their own systems or developed a system in close collaboration with an integrator, so that sufficient adjustments to the system could be made. **The more challenging aspect of the implementation was aligning the technology, the task it is intended to automate, and the current state of legislation and safety requirements. This has led to effects of cost explosions, additional safety measures that decrease system performance and, in some cases, a decision against installing the technology.**

It should be noted that challenges associated with worker resistance or low acceptance of the system were rare and have not resulted in an implementation failing.

4.4 Worker involvement

Involving workers actively during the implementation process can contribute to the successful implementation of a new technology in the workplace. Not only does it increase familiarity with the technology if workers are involved in the process, it can also lower resistance towards the automation. Depending on the circumstances, this involvement can start at the design stage or once training to use the technology starts. While there are external factors that can limit the extent to which workers can be involved, companies seeking to introduce AI-based systems should consider at what stage worker input can be included.

The timing when workers are actively involved in the implementation process is heavily dependent on company size and whether the system is bought from a third-party supplier or self-produced. In case studies (ID3), (ID4), (ID9) and (ID10), the technology was developed by the company, and in part by the workers who end up using it. Their input shaped the final technology. Case studies (ID1), (ID6), (ID8) and (ID11) either bought or are supplying finished robotic or AI-based solutions. However, a technology being bought from a third-party supplier does not necessarily result in lower acceptance rates from workers. Advanced robotics and AI-based systems becoming more readily available for companies to buy can have a positive effect on their overall distribution, because most potential end users do not have the means to create the technology themselves (e.g. farmers using the robotic systems presented in case study ID11).

Nevertheless, while early worker involvement is not always possible at the design stage, companies can seek to involve their workers as early as possible in the implementation process. This can take shape in informing them that the company is considering automating a task via an advanced robot. In addition, offering early notice on the upcoming implementation and providing them with the option to voice their thoughts and concerns, in order to address them, was found to be really important. The company in case study (ID3) also offers workers the opportunity to be reskilled to be a technology expert for certain types of systems, keeping them involved in the continuous automation process. **Companies with early worker involvement, within the case studies, report less resistance in their workforce towards the automation.** So, while not every company has the means or need to create their technology in-house, involving workers early in the decision process on automation that is to take place at their workplace is advisable.

4.4.1 Training and worker qualification

When talking about the automation of tasks, the question of which skills will be lost due to automation and what kind of new skills are required was frequently mentioned throughout our case studies: Regarding the development of skills, different requirements, depending on the system interaction role, arise. When using the technology as an assistive system, training, like for any new technology, might be sufficient in combination with learning by doing. Workers who are in charge of maintaining the systems may require further skills training, depending on their previous skill set. In other cases, certain skills might become redundant, as the system automates the part of the job that requires this knowledge. Therefore, skill-related changes in job and task structure have the potential to incite reskilling and upskilling workers, but they simultaneously hold the risk of deskilling. It is vital to be aware of the risk of deskilling in the workforce and mitigate it if possible or necessary. However, **some companies might choose to no longer invest in training their workers in a certain skill if it is not considered necessary for their job or is not seen as a high-value skill on the job market**.

Within the case studies, all three instances, reskilling, upskilling and deskilling, are described. Within almost every case study the companies take active efforts to upskill their workers. This goes hand in hand with the expressed desire to move their workforce into more highly qualified positions in the larger realm of automation. Upskilling typically includes additional training and education on the technology that they will be using at their workplace, including its functionality and basic error management, as well as in some cases more exhaustive explanations on how the underlying technology works. This training is sometimes provided by the company that developed the system and in some cases there is in-house training by technology experts; in some case studies, a developer and a user is the same entity. Workers are trained to use the new technology not only to handle it efficiently but safely as well. Case study ID6 includes basic safety training for all workers at the worksite to increase OSH. This is especially important in their case, as some safety features are invisible, and could be triggered unnecessarily, if not every worker at the worksite knows of them.

Selective case studies, like case studies (ID3) and (ID4) report that in the realm of upskilling, **entirely new positions have been created in charge of maintaining the system or even being involved in the implementation process for future systems**. This, however, seems to be the exception. These case studies also provide training and access to information about the latest developments in technology outside the immediate workplace. Workers can inform themselves about these topics in specialised courses and even have access to test technology (like a robotic system). This intends to increase familiarity with the technology and increase the workforce's overall understanding of current and future technologies, what their functionality is and how they can benefit workers who use them.

In some cases, like case study (ID8), the system was developed by the team that currently uses it and presents as a plug-in on a software that is already standard at their workplace. Hence, they did not see the need for additional training.

Reskilling is less frequently described, and when it is mentioned, it is usually connected to other upskilling measures. Working with a robotic or AI-based system and being able to use it is commonly seen as upskilling.

Deskilling is a complex process in the context of task automation. **In selected cases like case study (ID1), the company made the active decision to no longer train workers in the use of the industrial sewing machine that was replaced with the cobot.** They came to that decision after assessing which skills they would need in their future workforce. They then directed their energy towards providing said workforce with future-oriented skills and discontinuing said sewing training.

In many cases, like case studies (ID6), (ID8) and (ID9), the interviewees expressed that they explicitly need workers to maintain skills needed to perform the task. This is based on the fact that the technology either cannot cover all possible cases that might occur (ID6) or because there is additional use for the manually performed task differing from the system's output (ID8). **Another reason can be that the technology is not infallible. Case study (ID9) presents an AI-based system capable of detecting cancer with a higher precision than the clinician, however, it does not have a 100% detection rate. Hence, it is vital for the doctor to maintain their skill to catch cases that the AI might have missed.** This effect goes both ways, as the AI is especially proficient in detecting small instances of cancerous tissue that a human might miss.

While there is some deskilling occurring, the general trend is to upskill workers and provide them with both the needed training to use the new technology and possible skill sets that will stay relevant for the duration of their careers. Interviewees reported positive experiences in cases where they have been provided with education beyond the mere functionality of a system and also been explained the intended benefits it will have. Investing in providing workers with more than the needed knowledge to operate the technology, to further understand its functioning, can increase workers' feeling of control.

4.4.2 Level of trust and control

A moderate level of human trust towards one's work equipment including advanced robotics and AI-based systems promotes appropriate use.[24,25] However, extreme forms of trust can lead to adverse effects. Excessive trust can lead to automation complacency[26] and insufficient trust can lead to workers neglecting the technology.[27] If trust is miscalibrated in relation to a system's actual capabilities, problematic interactions can occur. Workers may 'misuse (over- or under-rely on the robot), disuse (stop using the robot all together), or abuse (use the robot for purposes other than as designed) their robotic counterpart'[28] if trust is mismatched. Trust in this instance can be defined as '*the attitude that an agent* [automation technology, i.e. advanced robotics] *will help achieve an individual's goal in a situation characterised by uncertainty and vulnerability*,'[29] however, during the interviews, the most common description in the realm of trust was that the system is performing its task reliably and safely.

Within the case studies, there was a reoccurring pattern regarding trust towards the system. In case studies where the company already had a high level of automation, or even other advanced robotics or AI-based systems, trust in the system was sufficient from the start. Workers reported being familiar with the technology and its capabilities, hence there was no foundation to mistrust it to perform tasks reliably and safely. Case studies for which the system was the first, or one of the first of its kind, encountered distrust towards the system more frequently. This distrust was often combined with a negative attitude towards the system and fear of job loss, as well as lower understanding of the technology. However, where interviewees reported mistrust or a negative attitude towards the system, there was usually a perception of the positive development of trust over time, as workers gained first-hand experiences. Experience helped to reduce fear of physical injury from the system.

Level of control is another relevant topic when it comes to the interaction with advanced robotics and AI-based systems. Advanced robotics or AI-based systems might be highly automated or even to some degree autonomous, which could result in them dictating a course of actions to the worker. There then is the risk that workers will experience a loss of control over their own work. Being aware of this risk has led many legislators and relevant stakeholders to highlight the importance of the 'human-in-control' principle. The European Trade Union Confederation (ETUC) published their 'Resolution on the European strategies on artificial intelligence and data' in 2020, which is a resolution paper regarding AI on a European level.[30] One of their key messages is that 'the principle of "human remains in control" should apply to workers and managers.' A similar stance is taken by the European cross-sectoral social partners BusinessEurope, SMEunited, CEEP and ETUC (and the liaison committee EUROCADERS/CEC) in their European Social Partners Framework Agreement on Digitalisation. This agreement is a shared commitment 'to optimise the benefits and deal with the challenges of digitalisation in the world of work'[31], including the notion that AI-based systems should follow the human-in-control principle. These publications are targeted towards AI-based systems, however, as the case studies show, the same notion could equally apply for advanced robotics.

In the developed case studies, control over the system is understood differently between the companies. Firstly, **there was no report of workers feeling a loss of control**. When the feeling of control over the

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[24] Parasuraman et al., 2000: A model for types and levels of human interaction with automation
[25] Hancock et al., 2020: Evolving trust in robots: Specification through sequential and comparative meta-analyses
[26] Parasuraman & Manzey, 2010: Complacency and bias in human use of automation: An attentional integration
[27] Hancock et al., 2020: Evolving trust in robots: Specification through sequential and comparative meta-analyses
[28] Ibid.
[29] Lee & See, 2004: Trust in automation: Designing for appropriate reliance
[30] European Trade Union Confederation, 2020: Resolution on the European strategies on artificial intelligence and data
[31] European Trade Union Confederation, 2020: European social partners Framework agreement on Digitalisation

technology was addressed, the case studies reported workers feeling in control of the system. In some cases, workers can actively control the system's involvement in the task, like in case study ID7, regarding the automated excavator, and case study ID10, where the gas vessel inspectors can plot a path for the robot but also control it manually. Especially in case study ID10, it was a design choice to create a system capable of switching modes, illustrating that keeping humans in control of technology must be an active consideration at the design stage.

In the **manufacturing and production context, the feeling of control over the system was bound more to the ability to start and stop the system**. However, in both manufacturing and production, the work environment is usually heavily standardised, so control over the work process by the worker was considered low. The automation has been attributed with freeing the workers' time and making them less bound to cycle times, thereby not necessarily providing them with more control over the system but with more time control overall.

There are some cases where workers have no control over the system. This particularly applies to case studies with an AI-based software running in the background supporting the worker. They can, in theory, switch the system off, if they switch the entire work system off, however, this is not a realistic scenario. Nevertheless, workers did not report a loss of control but rather that the system is integrated into the workplace so it is not necessarily noticeable during work. The AI in case study (ID4), for example, replaced a software that was performing the same task as the AI does now. The AI however performs the task more reliably. From the worker's perspective, not much has changed in terms of interacting with the system.

Another point is that most of the systems reported on throughout the case studies are mandatory for the workers. This is often due to their being installed as a safety measure or physical/cognitive support. Furthermore, production lines are adjusted to match the rate with the system in use. Only very few cases have the option to disable the system. Most noticeable in this regard is case study (ID6) where the trenching mode can be switched between autonomous and assistive mode. However, within the larger context of the excavation process, workers cannot refuse to use the system entirely either, as planning accounts for the increased productivity. Case study (ID8) also leaves it to the researchers to use the system as needed and annotate data by hand.

Overall, while workers often do not have excessive levels of control over the system, and predominantly must use them mandatorily, in the examined case studies, workers did not experience a loss of control.

4.4.3 Feedback system and report handling

The systems in place regarding feedback and report handling are highly dependent on company size, as well as the scope the automation has.

As an example, in case study (ID9), the company developed the AI-based system with the help of their entire team, and currently they are the only ones using it. Handling feedback is a very short process within their team. There is no formal feedback chain involved, as everyone is already involved in the project to a degree. Case studies (ID3) and (ID4) on the other hand represent a large, multinational company. They have several formal and informal avenues in place to handle reports and feedback. Particularly during the introduction process, worker feedback is sought out and encouraged, as the company has noticed that involving the workers early on helps to reduce negative feedback in the long run. There is a digital improvement suggestion system, in which each project has its own surveys and feedback box, as well as general feedback channels via persons of contact (supervisor or workers council) and a community network.

The case studies however largely describe the same approach to feedback handling, which is that any formally received feedback is taken into consideration and assessed for urgency and importance. This is then taken as a basis to decide which measures to take to address a problem or a wish for change. This also includes informal feedback, especially when it comes to worker attitude. Case study ID5 encountered initial resistance and scepsis towards their robot. They took these concerns into consideration and provided their workers with additional information on the safety and benefits of the system. This has resulted in workers' attitudes improving.

Importantly, no **special feedback system was introduced in any of the case studies, stemming from the AI-based system or advanced robotics**. In some cases, companies introduce a special feedback system for any wider workplace changes and this includes larger AI automation and robotic systems.

Regarding report handling of incidents, if case studies address this topic, they express that the company requires accidents and, in most cases, also near misses to be reported and filed, and this can lead to additional safety measures being installed. These reports are however handled on a case-by-case basis. This process was not changed due to the implementation of advanced robotics or AI-based systems.

4.4.4 Company culture and structure

The individual impact on company culture and company structure of each case study is difficult to compare. On the one hand, the companies are of various sizes and the extent of automation through the advanced robotics or AI-based system differs. Furthermore, many companies do not report any significant impact on these factors by the system. Hence, instead of summarising them, more valuable insight can be gained from selecting those in which the company culture or structure has noticeably changed.

For some case studies, the workers' social interactions and workplace social structure remained unchanged by the introduction of the AI-based system or robotic system. This is most commonly the case when there is only a singular system installed. Here, the companies often acknowledge that while a singular system does not impact company culture or structure, should the automation be expanded, both might be affected.

The case of case study (ID2) is especially interesting concerning the consideration of company structure. The automation was built as part of a new sawmill. Hence, there was no previous culture or structure to change. However, given how different the workplace is from traditional sawmill workplaces, workers having previously worked in the industry would need to accustom themselves to the new structure.

Another interesting social phenomenon that occurred in the realm of automation is described by case study ID8. The task that was automated was highly time-consuming and was disliked by the workers. Indeed, having this shared negative experience of the task prior to its automation had created a sense of comradery between them and an unspoken social divide between those who had to perform this task and those who did not. As the AI automated most of this task, the comradery and the social divide could have, theoretically, dissipated. Instead, the team reported that it had become more equal. The current state is preferred by the workers.

A unique social dynamic between the robotic systems and workers emerged in case study (ID4). They currently have more than 100 robots in the factory, and **an estimated 50% of these robots have their own individual names**. These names were given to the robots by the workers, not by the company. Reportedly, they are sometimes treated as a 'robot colleague', and actively being humanised and taken care of by the workers beyond routine maintenance. The company sees this as an indication of the high level of acceptance their workers have towards the technology.

In the larger context of digitalisation and automation of the workplace, some case studies report a shift towards flatter hierarchies in the social interaction between workers. The perception of supervisors and management shifts to them being perceived less as in their roles as supervisors but more as coaches or mentors.

Social isolation is also a topic that is frequently considered when talking about automation. However, **none of the case studies identified incidents of social isolation based on the introduction of the technology**. If an influence on social interaction was reported it was either neutral, for example, a workplace where a worker previously worked alone continued to have them working alone but now supported by a robotic system, or positive, as workers had more control over their time which they could use to help their co-workers.

Summarising, while the introduction of advanced robotics or an AI-based system does not necessarily lead to larger changes in a company's culture and structure, in select cases the impact can be far-reaching and should be considered before introducing the system to the workplace.

4.5 Risk assessment

Risk assessment in and of itself is one of the greatest tools for OSH. Before a cobot or AI-based system is integrated into a workplace, it is often necessary to perform a risk assessment. Considering OSH during the implementation is highly important. Considering it already at the design stage can help in maximising the potential a new technology has for the benefit of OSH. And we see through the case studies, companies involve the workers early in the implementation process to gather their feedback on the system, including their thoughts on OSH. This early worker involvement is credited to improve workers' acceptance of the system, by case studies (ID3) and (ID4). Furthermore, any steps taken to reduce risks and increase OSH benefit the company in the long run, as they not only reduce exposure to risks that would otherwise be missed, they also reduce the time and energy spent on installing revisions later in the process.

Most case studies have their own internal risk assessment system, which according to them can be stricter and more detailed than some legal requirements. However, in the experience of some case studies, the current necessary efforts for risk assessments have been negative and described as more of a hindrance to OSH than an enhancement. The currently available tools for risk assessment are perceived as insufficient and not suited for the technology. They lack the flexibility to reflect the increasingly complex abilities of today's technology. Therefore, some case studies report that they must comply with standards made for systems with fewer safety features and more inherent risk than their technology, which results in additional, and to them, redundant, safety measures being taken. As mentioned above, this process has led some companies to the decision to not install cobots at specific workplaces, but rather fully automate the space with a robotic cell. Especially current norms are criticised for not reflecting the technology in its current state and abilities. In some cases, the advanced systems could not be installed to perform at their full potential, which under today's technological abilities was judged to be safe by companies, as they would not conform to external risk assessment standards. That way, potential OSH benefits of the system could not be reaped. In selected cases, the measures that would need to be taken after risk assessment were described as so extensive that projects launched to install advanced robotics were shut down.

Considering the standards and legislation, as well as OSH in general, during the early design process can protect companies from encountering some of these issues during risk assessment of the final system. This however is only possible if the company either develops the system themselves or has significant input during the design phase. Companies that buy their system from a third-party supplier should focus especially on the inclusion of the new systems in their OSH management system in the early stages, to be able to react swiftly and efficiently to any concerns arising during the implementation or shortly thereafter.

There is a reported need for comprehensive risk assessment tools that reflect the current abilities and limitations of today's technologies. This need to runs in parallel with legislation and norms reflecting modern technology. While it is understandable that there is a gap between the technology studied when legislation is being written and the newest innovation available, this gap should not grow to the extent that the implementation of new systems comes with such intense additional adjustments that companies consider not installing these systems at all. All case studies show that the OSH benefits of their systems outweigh any of the potential risks. The use of technology to improve OSH was an almost unanimous main goal, driving the introduction of the system in the first place, and it continues to be a driver for future implementation.

4.6 Barriers and drivers during the implementation process

Many companies go through the process of integrating advanced robotics into their workspace for the first time. The presented case studies encountered a variety of barriers and drivers throughout this process. Identifying these can help companies as well as others, to avoid barriers and promote drivers for their process automation.

4.6.1 Barriers

When it comes to barriers hindering the implementation of advanced robotics and AI-based systems, there were several general themes that emerged, which we now outline. Alongside the themes, some local barriers could be observed in some case studies.

Legislation

A repeatedly named barrier hindering the implementation of advanced robotics and AI-based systems was the current state of regulation, both national and EU-wide. They were perceived as not sufficiently reflecting the advantages or capabilities of current technologies, and thereby limiting their application severely. This also applies to many standards, which were described as being based on older technologies. Limiting an AI-based system to standards that were developed for systems with fewer capabilities (especially regarding OSH) means that (robotic) systems might not be introduced in an impactful or meaningful way. While safety must not be compromised, cobots in particular have become increasingly safer to work with through increased abilities to perceive their surroundings and react accordingly. However, it is stated that these new technological abilities are currently not represented in the standards that they must comply with. Some companies describe this as an unexpected extent of safety requirements and documentation. Especially introducing a cobot to a workplace can in some cases be accompanied by a higher demand for documentation and more complex safety regulations and concepts to consider and implement. The paperwork needed to document everything appropriately can significantly slow down the process. The risk assessments have in some cases led to safety measures that make a project financially unfeasible. It has to be noted that the ISO/TS 15066 at the time that this report is written is undergoing revision with the intent to integrate it into the EN ISO 10218-1 'Robots and robotic devices — Safety requirements for industrial robots'. Adjusting today's technology to these standards without creating an inefficient system proved to be a time-consuming process for some companies. One of the interviewees summed this up as: 'Newer technology demands newer standards'.

Worker resistance

While highly motivated workers were a driving force in the success of the technology implementation, the opposite, change adverse workers, seem to be an equal barrier. **This group has multiple reasons to reject the technology, spanning form fear of job loss to cognitive overload from the rapid changes and raised cognitive expectations at their workplace.** The fear of being replaced by the system as well as a low understanding of technology were identified as contributors to the aversion. There are selective reports where workers did not fulfil their maintenance or supervisory duty towards the technology if the aversion was not sufficiently addressed. Facing resistance from the workforce can be a major hindrance when introducing a new technology to a workplace, hence it is vital to identify the reasons for resistance as early as possible and address them accordingly.

Lack of European focus

While collaboration with other companies was perceived as a driver for the implementation process, **companies noticed the lack of European case studies as a barrier and hindrance**. Currently, the most prevalent and easily available case studies are based in Asia. This results in a number of problems for companies based in Europe that want to learn from their experiences. Asian countries, generally speaking, operate under different work and OSH regulations, as well as possibly other technological requirements. The differences in legislation severely limit the applicability to the European market. While it is possible to gain insight from case studies outside the EU, this process can be time consuming and there always needs to be additional resources allocated to gauge the applicability under current EU requirements.

Integration process

Lastly, matching the new technology to the existing production line was a challenging task for some case studies. Often, the systems into which automation is integrated were built decades ago. Hence, it is difficult to make the newer technology compatible with them, while adhering to all necessary safety regulations. While cobots and AI-based systems are a flexible tool, integrating it into a pre-existing production line might limit flexibility considerably. Technical complications in these combined systems seemed harder to foresee. This can relate back to a lack of experience with the technology overall. However, technical engineers are gaining experience with the system and can avoid malfunctions.

4.6.2 Drivers

A driver for the implementation of advanced robotics and AI-based systems can be a wide variety of things. A suitable robotic system being newly available on the market can be considered a driver for furthering automation in a company. However, unless a company is actively developing their own robotic solutions, or have significant experience with such systems, this kind of factor is difficult to influence a company looking to automate tasks with a cobot or AI-based system. While it is important to identify drivers that lie outside the direct influence of a company, being aware of those within their company can be more effective to facilitate a successful implementation of the new system.

Worker motivation

Among all interviewed companies, the most named driver that was attributed with the successful integration of advanced robotics and AI-based systems was highly motivated workers. This was used as an umbrella term to cover a variety of characteristics and expressions of this motivation. Workers were described as open to change and generally expressed having a high affinity for technology. These workers were able to anticipate and accurately understand the benefits of the technology quickly and they engaged with it more actively once it was installed. In some cases, these highly motivated workers even requested additional training to expand their responsibilities towards the technology. This facilitated training and general upskilling.

Exchange of expertise

While advanced robotics and AI-based systems are becoming more common, for many companies they are still a novel technology. Hence, the overall level of experience is considered rather low when compared to more established machines. **A driver that was repeatedly listed by companies was collaborations and exchange between other companies**, which either already used a similar system or were also currently in the process of implementing it. Exchanging their experiences and expertise on implementing the technology has been perceived to be highly beneficial to the implementation process. This exchange was not only limited to other companies. Collaborations and consultations with universities were also seen as beneficial. Newly developed systems involving external researchers can benefit both parties.

First-hand experience

While the exchange of expertise is beneficial in the process and also before implementing these systems, actual first-hand experience with the process and the system itself has also been accredited to be a major driver of long-term success. The more experience everyone in the process had, from management to technology engineer to OSH personnel to the workers, the more successfully a project was handled. This is particularly noticeable with workers. Gathering first-hand experiences with the cobot or AI-based system has been reported to reduce fears, for example, of physical safety, and increase positive attitude towards the technology. There are illustrative examples of how these technologies become integrated not only in the production process but also into the social structure of a company. Some received individual names and were playfully humanised by being referred to as ‘colleagues’. This positive development is based on repeated interaction with a system, which cannot be artificially accelerated.

Early worker involvement

While first-hand experience with a new technology to form individual opinions and trust towards a newly implemented technology cannot be artificially rushed, companies have possibilities to facilitate this process. However, early worker involvement is a relevant driver for a variety of reasons. Firstly, the earlier workers are involved in the process of implementation, the earlier they can familiarise themselves with the technology. Early involvement also affected other areas. It can be somewhat challenging to pinpoint exactly when early worker involvement begins. In some companies, workers can actively request the implementation of new technology at their workplace. In this case they are theoretically involved from the start of the implementation. In other companies, workers can play an active part in the design of a future robotic system, especially when the company does not rely on a third-party supplier but develops their own systems. For other companies, decisions might be made on a global scale, with already designed systems where workers have a limited chance to participate in the implementation process. However, companies reported that involving workers early in the decision-making process has had a positive effect on technology implementation.

4.7 Integration of OSH management

Figure 6: Manaagement Cycle by the ILO

The introduction of new technologies, like advanced robotics or AI-based systems, can lead to a change in work procedure, including OSH. Therefore, the expectations placed on the technology and subsequent OSH management need to be taken into account.

The ILO published **'Guidelines on occupational safety and health management systems, ILO-OSH 2001'**, which have become a popular model for developing national standards, but also for companies to consult and orient their OSH management along those guidelines. The guidelines contain a system of continual improvement of OSH in what they call the OSH Management Cycle[32] (Figure 6). While not explicitly referring to the ILO as inspiration for these steps, many companies follow a similar cycle in order to continuously improve OSH. In order to ensure OSH for the use of advanced robotics or AI-based systems at the workplace, companies should include the technology as early as possible in their OSH management. While including such systems is not noticeably different, in principle, to other technologies, some companies have noticed that particularly during the initial steps, with regard to OSH policy, this process can be very time consuming. Most companies do not yet have extensive experience with the integration of these types of technology, hence, the initial implementation stages can be time-consuming.

4.7.1 Emerging OSH risks and monitoring

With any new technology, there is the potential for new OSH risks to emerge. While there are some that can be apparent during the implementation process, others might only arise over time. Knowing where potential risks could arise can be rather difficult with advanced robotics or AI-based applications, due to a lack of experience within many industries with these systems and their continuously changing abilities. Some case studies have developed successful strategies to monitor for new and emerging OSH risks.

[32] See: https://www.ilo.org/safework/areasofwork/occupational-safety-and-health-management-systems/lang--en/index.htm

Workplace inspections that are carried out by work safety specialists and possibly a technology specialist on a regular basis can identify possible new threats, based on time-dependent factors like wear. Another way to anticipate developing OSH risks in advanced robotics and AI-based applications is the active involvement of workers. Several companies create specialised worker feedback systems through which workers can alert any changes or concerns based on their first-hand experience with the system. These steps are taken in addition to several built-in features of many systems. Particularly in case studies with advanced robotics, the systems often perform initial checks on themselves before starting operation. These checks typically include a status check of all internal components, as well as the check if all external safety measures are in place. If possible, some companies have also introduced a specialised system to report system-related near misses and accidents to increase their knowledge on what to look out for and thereby monitor.

For AI-based applications, a tool used by some companies is specialised audits with the sole focus on workplace safety, and possible ethical concerns about the decision process of the AI.

While all companies agree that some form of OSH risk monitoring with autonomous systems is important, they also highlight that these monitoring measures need to be in line with the right for privacy of their workers.

4.7.2 Communication strategies

Communication is an important tool before, during and after the implementation of advanced robotics and AI-based systems. Most case studies have a functional communication strategy for their workers in place. Empirical research supports the companies' experience that having a formal communication avenue while introducing a change initiative reduced uncertainty and enhanced commitment.[33,34] Communicating future changes to workers can reduce feelings of uncertainty towards the rationale behind the change. **Furthermore, clear and direct communication has been found to promote change-supportive behaviour from workers.**[35] All these findings in literature were reconfirmed in the experience of the case studies. Having both personal (e.g. team lead) and anonymous (e.g. feedback box, or via workers council representative) communication systems has been described as helpful to receive worker feedback and create conversation around relevant topics. How the case studies handle feedback and reports regarding their systems is already described in section 4.4.3.

However, communication should not stop once a system is installed. It is important for companies to keep channels of communication open to react to any arising changes. Furthermore, some case studies utilise the dialogue with their workers as an OSH measurement. They understand that the operators who use the system daily have a different understanding of the system and can provide valuable unique insight into possible rising OSH concerns.

4.8 Cybersecurity

With technology becoming increasingly interconnected and data itself being a resource needed by some AI-based systems to improve their functionality, the topic of cybersecurity becomes prevalent in companies employing these technologies. How the topic of cybersecurity is handled is a key factor in securing the data when it comes to AI-based systems. Some systems require additional safety measurements, depending on their use.

However, companies in most case studies did not take any additional measures towards cybersecurity. Most robotic systems are not connected to the Internet or connecting vital servers and are therefore not considered a feasible target. While malware entered via a direct connection (like a USB) could potentially give someone control over, for example, a singular robotic system, the high-risk low-reward situation of the attacker makes a cobot an unlikely target. The hypothetical case of a robotic system controlled by

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[33] Bordia et al., 2004: Uncertainty during organizational change: Types, consequences, and management strategies
[34] Hobman et al., 2004: Perceived dissimilarity and work group involvement: The moderating effects of group openness to diversity
[35] EU-OSHA, 2022: Cognitive automation: implications for occupational safety and health

an outsider is also largely considered unlikely and a low OSH risk, as these systems typically have emergency stops. The systems move within set boundaries regarding their speed and strength and are unlikely to injure someone. Hence, most companies do not add additional cybersecurity measures. When it comes to largely AI-based systems, companies are aware that there are hypothetical risks of outside interference. One example was named where someone could influence a human resources system to increase bias (it is important to note that this was a short case, and not a fully developed case study speaking from experience). These scenarios are also considered unlikely.

Targeting singular applications from the outside is considered an unlikely scenario, both for AI-based systems and advanced robotics. Cyberattacks meant to harm a company are described to rather attack larger digital infrastructures of said company. Using, for example, the AI in case study ID9 to gain access to sensitive hospital data is also seen as unlikely as it does not provide a point of entry to the larger digital infrastructure.

However**, the fact that no new and additional measures were taken, does not mean that these systems are unprotected**. **When no additional steps were taken this was done so under the knowledge that the case study already has extensive and sufficient cybersecurity measures in place for their production lines, workplaces, clients and digital infrastructure that the new technology could be covered by these.**

Within the context of cybersecurity, data privacy is also a concern both on the workers' and employers' end. Some AI-based systems either handle or collect person-related data, which creates the need for additional worker protection. Firstly, most companies that have systems that could collect sensitive data (e.g. pedestrian detection on an excavation site in case study ID6) take sufficient and extensive measures to protect their workers' privacy. This includes reducing the collection of data to the minimum, informing workers if, where and when possible, data collection takes place, and generally adhering to the current laws of data privacy protection. In none of the AI case studies is data collected with a link to workers' identity. In case study (ID6), where it can happen that a worker enters the field of vision of a camera system, the worker is not identified on a personal level, and the video material is not stored. In case study (ID7), the only time the camera is positioned towards a worker is during calibration, and to protect this worker's privacy they developed an algorithm that cuts out everything from the calibration video that is not the calibration grit. The protection of workers' privacy when working with these systems is a topic case studies are highly aware of and take active measures to increase.

4.9 Organisational and social impact

While the impact that technology can have on workers and their surroundings often is primarily assessed with regard to the tasks automated, they can also impact the social structure of a company. Frequently, concerns of social isolation are brought up. However, based on the case studies' experiences, this concern could not be confirmed. Predominantly, cobots are introduced at workstations where previously a worker performed their task without another worker's assistance. In these cases, the cobot did not increase or decrease the number of social interactions at the workplace. However, there are two phenomena related to the social impact of these systems. Firstly, the changes in task structure and job routine have in some cases resulted in the worker having more control over their time, which they spend assisting their colleagues, **increasing the amount of social interaction** overall. In some cases, cobots led to a restructure of work cycles, which not only made the job demands more balanced but also encouraged social interaction as workers were not bound to one post for an entire shift.

The second phenomenon is the inclusion of advanced robotics or AI-based systems in the social structure of a workplace. There are incidences where the acceptance towards the systems has become so high that workers have assigned the individual systems names and address them as such. While there are robotic systems that come with pre-assigned names, workers taking the initiative to name them individually is interpreted by the case studies as an indicator of high acceptance and trust and low negative attitude or fear towards them. Especially trust is seen as an antecedent for safe and effective human–robot collaboration.[36] Systems that are accepted to such a degree are less likely to be misused or neglected, resulting in workers receiving the full extent of possible OSH benefits from the system.

The most significant organisational impact on OSH happens when the technology is being used to break up previous routines at a workplace in favour of more ergonomic routines. This becomes especially apparent in case study (ID7), which introduced the AI–robot hybrid to reduce the need for night shifts in the factory's location. Night shifts are associated with numerous adverse health risks, such as cardiovascular disease, cancer, diabetes, injuries and negative pregnancy-related outcomes.[37] These negative effects can be avoided if workers need to perform fewer night shifts or no night shifts at all. Thanks to the vision system, the delivery process needs significantly fewer workers, who can now work primarily during the day shift. Similarly, case study (ID5) also used the potential the automation brought to their workplace to change their organisational structure. Before the implementation of the cobot, a worker would stay in the same post for eight hours. Now there is a rotation system in place where workers change station every two hours. All workers are trained to operate the cobot, and perform the task at other workstations, so that they can transition seamlessly. Workstations differ in their level of cognitive and physical demands, so the rotation is a way to balance the overall demands on workers.

These two case studies highlight how advanced robotics or an AI-based system can benefit OSH via organisational changes they incited. Both companies saw the technology as a tool not only to automate a specific task but also to change the workplace structure to the benefit of their workers. Companies that are planning on installing a robotic system or an AI-based system should assess the impact the system can have on the larger work environment and see if they can identify OSH benefits, or risks, that would arise from larger organisational changes made possible by the technology.

5 OSH impact

The introduction of an AI-based system or a collaborative robot can have a wide impact on OSH. It can pose several challenges as well as opportunities unique to each case study. In addition, it is important to identify possible barriers and drivers to consider them in future projects. This new form of task automation can even lead to changes in the overall OSH management of a company. Through the interviews a number of these factors have been identified and discussed.

5.1 Challenges for OSH

As cobots allow highly individualised solutions for a company, they might also present challenges specific to their case study. In addition, more universal challenges can emerge, which the company then has to address. The interviews contained a few OSH challenges the companies had to face, both during the implementation phase as well as in ongoing production.

5.1.1 Qualification / deskilling

While upskilling and reskilling are listed as a frequent opportunity associated with the introduction of advanced robotics and AI-based systems, the effect of deskilling is explicitly named less frequently. However, some companies acknowledge that in the process of automating their workflow specific skills become redundant and are no longer trained. The decision to stop training these skills is based on an assessment of which skills are seen as important in the future for the worker and the company. Hence, deskilling typically does not occur without re- or upskilling of some form.

Simultaneously, while companies focus on upskilling their workers, there also is a reported gap of highly skilled and specialised personnel to implement and maintain these systems. The consequence of this is not that unqualified personnel are assigned these tasks, or that the systems are

[36] Hancock et al., 2011: A meta-analysis of factors affecting trust in human-robot interaction
[37] Garde et al., 2020: How to schedule night shift work in order to reduce health and safety risks

implemented without sufficient oversight, but rather that less of them are installed. This comes at the cost of all potential OSH benefits workers would have from these systems.

5.1.2 Cognitive overload

While the above-mentioned process of upskilling and expanding worker qualification is an opportunity, the increased mental workload that these changes bring can be a challenge. Companies report that workers need to acquire new skills in a short amount of time, while also adjusting their working routine. This can be a change people struggle to adapt to, as well as a challenge for some workers to meet the increased cognitive demand of their job. Lastly, while most case studies state that the automation of tasks through either advanced robotics or AI-based systems intends to move workers into higher, supervisory jobs, with more impactful decision-making, it has to be acknowledged that not every worker desires this type of work. While the automation of tasks is often described alongside the automation of dull, dangerous and dirty jobs, when it comes to routine-based work, some workers seem to prefer a reliable routine. Changing their daily work from a highly structured, foreseeable pattern to a more flexible workday can result in resistance.

5.1.3 Demographic changes

While a change in worker demographics in and of itself is not a risk to OSH, it does play a vital part in the motivation to use advanced robotics and AI-based systems. Within the manufacturing sector skilled and experienced workers are retiring, and companies struggle to find replacement. Companies may try to compensate by increasing their efforts to automate production, which possibly increases the fear of job loss in existing staff. In addition, older workers have reportedly had more difficulties learning to use the new technology as well as lower acceptance rates than younger workers. Workers of a higher age have also reported more difficulties to adapt to changes in their work routine and experienced more difficulties to keep up with the continuous need for training and acquiring new skills. The challenge for OSH here is, on the one hand, to motivate workers to use the technology that is intended to support them, and enable them to stay in their jobs longer, as well as to decrease the level of stress they experience from working with said technology.

5.1.4 Fear of job loss

While only two of the case studies report that they actively encountered fear of job loss during their implementation process, most of them acknowledge that this is a problem likely to occur when automating tasks via advanced robotics or AI-based systems. While all companies state that their intention is not to eliminate jobs but rather move their workers into more fulfilling positions through training, the fear of losing one's job seems to prevail in the initial phase of introduction, despite extensive education and worker training. Measures that have had a positive effect were additional education for the impacted workers on how the technology is going to make their work easier and safer, as well as information on how the automation will restructure their work and responsibilities. A factor in contradiction with the present fear of job loss is most companies' problem in finding qualified or experienced workers. Most case studies prefer to keep the expertise of their workers within their company, only use it in a more efficient way. If companies can communicate these intentions successfully, they can decrease the fear of job loss in their workforce.

5.1.5 Physical risks / residual environmental risks

Another challenge simply is the residual physical and environmental risks that remain when working with machinery. While all systems undergo risk assessment to ensure as much safety as possible, there will always be a residual risk of injury from unpredicted malfunction, misuse or human oversight. It is important that workers are equally aware of this as they are of the safety measures of these systems. Most companies take a number of measures to address any residual risks. This can take form as additional safety signs or invisible barriers that if crossed activate an automated stop in the technology. It must be mentioned that residual physical risks only occur if the technology has some form of physical representation.

5.1.6 Fear of injury

As previously mentioned, many companies assess working with their system to be extremely safe, without any actual danger to a worker, if they perform their tasks as intended, do not misuse the technology and ensure that maintenance is performed on the required regular basis. Under these circumstances, working with cobots, AGVs or AI-based systems is safe for workers. The remaining risk of injury mentioned in the previous section is described as inherent to working with machinery and does not exceed the risk of traditional automation technology. However, there are instances where workers report fear of the technology. Here, the timing of these reports must be considered. Workers who reported fear of physical injury from the system did so primarily before or within the initial days of working with the system. This fear decreased as workers experienced themselves that the system is safe to use.

It is important to take fear at the workplace seriously, regardless to which extent there is an objective risk or a subjectively perceived one. Workers who are afraid of the system do not trust it. Trust is one of the fundamental antecedents to safe and effective HRI, hence, fears should be taken seriously by an employer. They can address these fears via specialised training or safety demonstrations.

5.1.7 Unpredictability

Unpredictability is often associated with self-learning systems. However, companies make it a point to stress that, while possible, should a continuously learning system be employed at a workplace, this is simply not the current state of procedures. AI-based systems are trained before their implementation, on special training data. **Continuous, unsupervised learning during everyday work is not common practice. Hence, companies are aware of the possibility, but it typically does not apply.** Case study (ID7) does report behaviour of their AI-based system that did not match their initial expectation; however, this mismatch did not result from the system continuously learning and adjusting its behaviour, but rather from the initial parameters of the set-up. With this AI, as in all other AI case studies, the system does not continuously learn during work hours, but rather gets updated outside of active operation.

5.1.8 Task consolidation / job structure

Increased task consolidation is another challenge some companies, or specifically their workers, face. Workers might now be responsible for more challenging tasks, while being able to exert less control over the outcome. If they previously assembled a workpiece themselves, the pace and quality was entirely in their control. Now, as they take on a more supervisory role, they have less control, while still being responsible for the outcome. For some workers they might also face significant changes to their job structure, after the introduction of advanced robotics or an AI-based system. This change in structure can be difficult to navigate for some workers. It is possible that they must restructure their familiar routines. This leaves workers with a possibly less balanced job demand throughout the day.

5.1.9 Decreased task completeness / task structure

Through the introduction of advanced robotics and AI-based systems, tasks tend to become more disjointed, leading to more task switching. Previously, it was not uncommon for workers to work on a piece from start to finish. Now, workers are doing more and more side tasks, next to their primary tasks, as the advanced robotic or AI-based system has automated the majority of it. Throughout the workday they have to task-switch more often, and less frequently perform a complete process. Their workflow might be more disrupted than before. This can decrease the feeling of completeness and accomplishment in workers.

5.1.10 Negative attitude / trust

Within the context of fear towards the technology, negative attitude also poses a challenge for OSH. Some workers have a more negative attitude towards technology than others. This does not need to be specific with regard to robotic systems or AI-based systems, however, they generally are included in these attitudes. A negative attitude can have many sources. The above-mentioned fear of job loss, lack of trust or fear of injury can contribute to it. However, as many of these systems are mandatory to use, workers will have to perform their task with a technology they hold negative feelings towards. This can potentially be negative for their job satisfaction or wellbeing. To change someone's attitude, the root cause must be identified, so that interventions addressing it can be planned. **As a final note, several interviewees within case studies expressed the wish for more accurate media coverage of what advanced robotics and AI-based systems are, and especially the potential they hold to improve not only OSH but also everyday life, when used responsibly.**

5.2 Opportunities for OSH

Next to the above-listed challenges for OSH, the implementation of advanced robotics and AI-based systems can also come with numerous opportunities for OSH. While there are some shared factors between technologies that focus on the automation of physical and cognitive tasks, there are also some unique to each technology.

5.2.1 Worker qualifications

Worker qualification, and the improvement of it, is among the most frequently named opportunities. Many companies use the introduction of advanced robotics or AI-based systems to expand their workers' skill set. This is not only to allow them to use the system effectively and efficiently, but also to expand their knowledge to other working areas and equip them with skills that are considered valuable in the future. While there is discussion on the matter of deskilling as a result of automation, companies primarily focus on **upskilling** and **reskilling** their workers.

5.2.2 Physical workload and health

Physical workload and health are the most commonly anticipated and experienced opportunities when it comes to advanced robotics and AI-based systems. This can be in the form of supporting the worker to avoid long-term strain injuries, removing them from hazardous working environments, reducing their workload or avoiding accidents. This benefit is so far predominantly occurring during the automation of physical tasks through a robotic system. AI-based systems for the automation of cognitive tasks have not been attributed with this effect. Nevertheless, the improvement of workplace ergonomics is a primary goal for most companies when introducing these types of technology, and in every case study that stated this as a goal, they report that the technology has succeeded in accomplishing this goal.

5.2.3 Mental workload

The optimisation of mental (work)load is another commonly encountered opportunity when it comes to both AI-based systems and advanced robotics. The effect can take place over a variety of factors, such as the reduction of input that has to be assessed by a worker, less workload in general, as the system prevents unnecessary iterations of the task, and the system preselecting which information to display to workers. These are typically found when AI-based systems automate cognitive tasks. However, systems that automate physical tasks have also been attributed with having a positive influence on the cognitive load and wellbeing of workers. When these systems perform their task reliably, this alleviates the worker from having to plan and perform that task, and in some cases reduces their need to anticipate processes or previously necessary mental energy that went towards mentally monitoring their safety during their task performance (i.e. a worker lifting a heavy workpiece might allocate mental energy to assess the risk of dropping the piece by accident; when a cobot lifts the piece, they do not need to spend mental resources on this).

5.2.4 Increased task variety / monotony reduction

Increased task variety or reduction of monotony is attributed to most advanced robotics and AI-based systems. In accordance with most literature, these systems are often used to perform repetitive, monotonous tasks. The worker is then assigned either more interesting or challenging tasks, or can allocate more time and resources towards the remaining tasks they perform with the system. Some companies have even taken this opportunity to restructure their workflow entirely. Specific for robotic systems in the automation of physical tasks is also a shift of their job focus. The worker performs fewer physical tasks and more cognitive tasks as a result of automation.

5.2.5 Job control (control over workload)

Job control tends to increase when autonomous systems are introduced to a workplace. This can happen through a variety of avenues. In some cases, the system can be used to prepare material before the worker needs it, creating a buffer of material that the worker can access. Many systems increase the workers' ability for time allocation (i.e. AGVs can be used by a worker to receive supplies without having to spend the time to retrieve them themselves. This freed time can be allocated by the worker where they need it at that time). Many of these technologies can also be programmed to operate independently from humans to a certain degree. This frees the worker to perform other tasks in the meantime or allocate their tasks towards other activities in general.

5.2.6 Wellbeing

Wellbeing is often named as an opportunity to address various factors. This opportunity is often named as an unspecific benefit resulting from the overall changed workplace circumstances. An increase in wellbeing is attributed to an increased ergonomic design of the workplace due to the new technology, to the prevention of injuries and the reduction of physical risk during work, and the reduction of monotony, to name a few. While it is possible to develop advanced robotics or AI-based systems that target worker wellbeing (e.g. an AI-based counselling chat bot), none of the case studies dealt with such systems. The increase in wellbeing is seen as a by-product of automation. However, companies should be aware that the technology they implement can have these effects to measure and enhance them.

5.2.7 Screen time reduction

Screen time reduction is one of the opportunities primarily associated with the automation of cognitive tasks. When an AI preselects or presents information the worker needs in a more comprehensive way, it reduces the time they spend looking at a screen. This can also reduce strain on the eyes of workers. It has to be noted that this is not a universal effect. Screen time reduction can only occur if the job contains tasks that are not bound to working on a screen. Case study (ID9) reports no changes in their screen time, as all of their primary tasks are performed on a computer as well.

5.2.8 Positive social change in the workplace

Social interaction, or its negative expression of social isolation, is one of the more frequently named risks of these technologies in the literature. However, based on the experience of companies using these systems, they have at worst had no effect on the social interaction within the company, or a positive one. The situation is described as neutral when the systems support workers in tasks that were previously performed by them alone. Positive effects on social interaction are attributed to workers having more time to interact with and help one another due to the systems, or experience more interactions because their job routine changed. Interestingly, there are also cases where the systems have been integrated into the social structure of the company where workers refer to them by name and as their colleagues.

Furthermore, some interviewees within case studies mentioned that the introduction of these systems within a larger push towards automation at the workplace has resulted in a perceived flatter hierarchy. While this happened in a context where social interaction between co-workers and especially their supervisors was already described as positive, flatter hierarchies and the increased positive interaction between workers can potentially have positive effects on people's mood, job satisfaction and wellbeing.

5.2.9 High-risk groups and inclusion

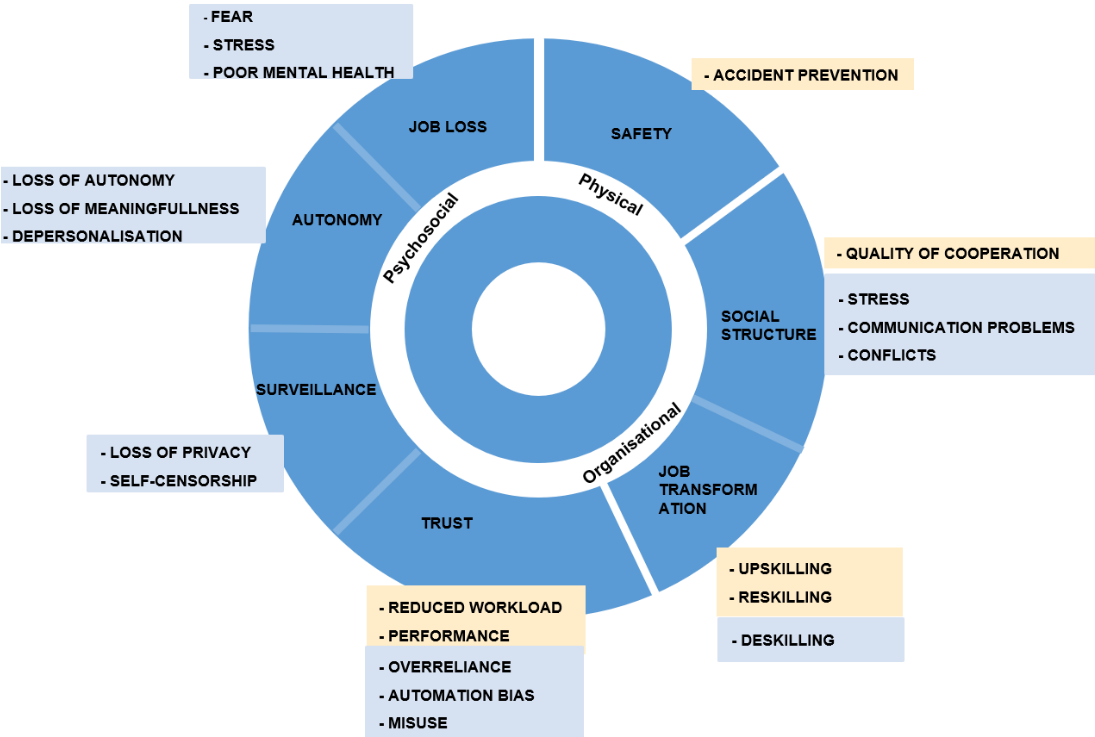
Advanced robotics and AI-based systems also hold the opportunity to support inclusion at the workplace. Primarily named in the context of physical task automation, these systems hold the potential to make workplaces more accessible to workers with different needs.

Specific groups can face unique OSH challenges. While the interviewees noted that most demographic factors like age and gender do not face any specific risks, height could be considered a factor. As previously mentioned, worker height was a factor when setting the speed boundaries of the cobot. It was set so that shorter workers can interact with the system as safely as workers of average height. The interviewees noted that creating a safe and healthy environment for all of the workers can sometimes be difficult as in a standardised production one often has to take the average person as a basis, and not everyone is covered by this. However, age seems to be a dividing factor between the workers' first-hand experiences with the cobot. **While younger workers seem to be more open to the idea of robotic automation and interacting with the robot, older workers appear to be more change-resistant.** In addition, older workers seem to need longer to acquire the new skills needed to use the cobot, or do not understand the technology. So, while older workers do not form a risk group in particular, workers with an aversion towards their means of working, as well as limited understanding of it, pose a higher risk in general.

5.2.10 Differences in expected and experienced OSH challenges and benefits

Based on a previously performed extensive literature review, we have a comprehensive overview of factors that are expected to be relevant to OSH. These results are based on the current state of research regarding advanced robotics and AI-based systems. When comparing these factors to the OSH factors named by interviewees in the case studies, one must take into consideration the completeness of information on either side. Figure 7 and Figure 8 present the accumulated insights on OSH from around 183 publications, presented in previous EU-OSHA's reports[38,39]. Figure 9 is based on the case study reports of the nine selected companies. They are not representative of all sectors and areas of application. Nevertheless, there are insights to be gained from comparing the two overviews.

Figure 7: Overview of OSH- relevant factors and effects of AI-based systems based on literature review



38 EU-OSHA, 2022: *Advanced robotics and automation: implications for occupational safety and health*

39 EU-OSHA, 2022: *Cognitive automation: implications for occupational safety and health*

Figure 8: 0verview of OSH relevant factors and effects of advanced robotics based on literature review

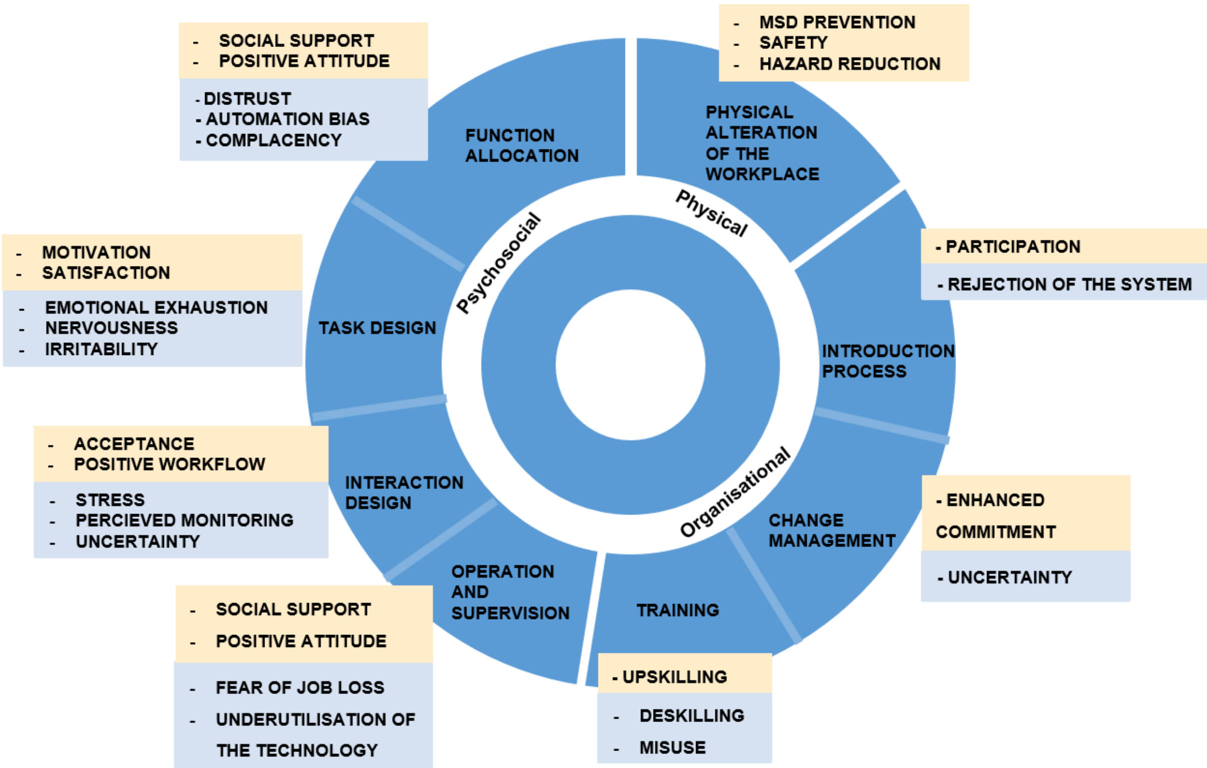
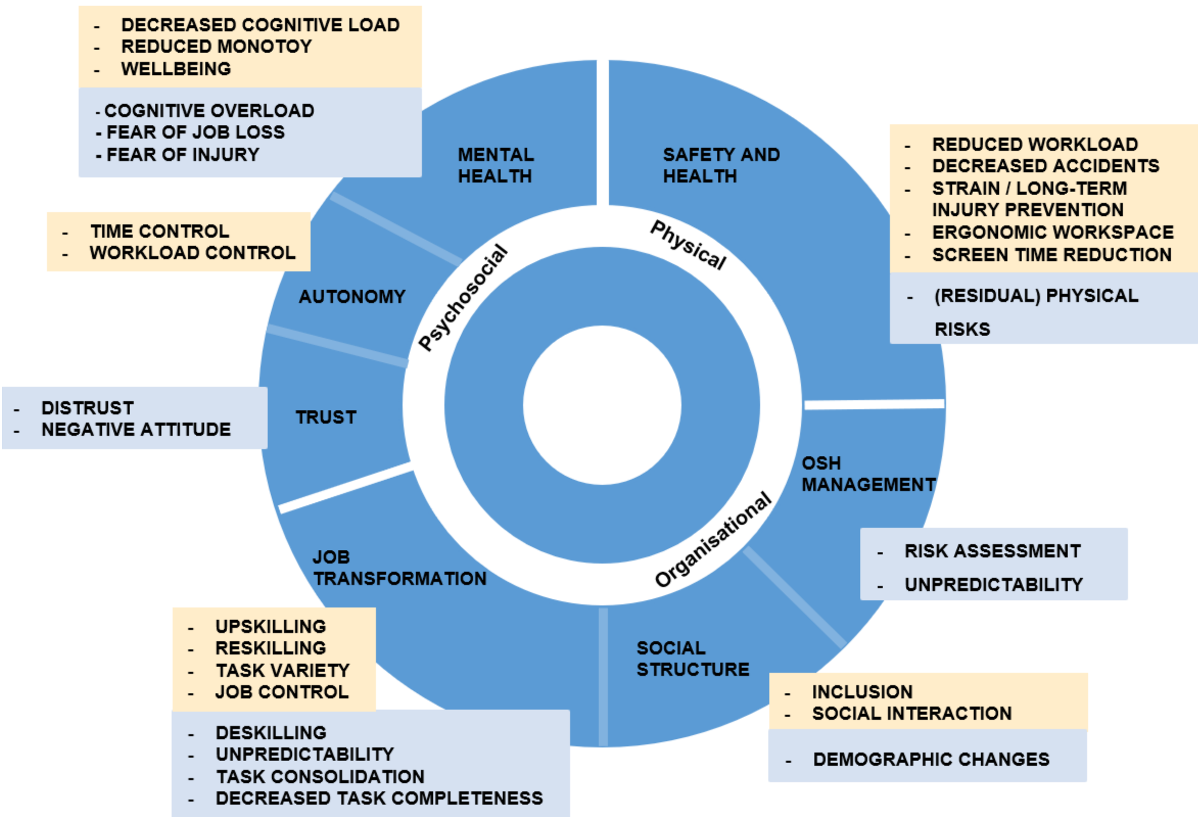


Figure 9: Overview of OSH-relevant factors and effects based on company experience



The implementation of advanced robotics or AI-based systems comes with challenges, risks and opportunities for OSH. However, the case studies demonstrate that the OSH opportunities outweigh the challenges and risk. When comparing the two graphics it becomes apparent that the interviewees within the case studies reported a significantly higher number of OSH opportunities than those extracted from the literature. It has to be taken into consideration of course that the different challenges and opportunities are presented at different degrees of abstractness. Screen time reduction, for example, is a very specific OSH opportunity, only applicable for technology that previously had a worker use a screen for a long period of time. However, benefits like upskilling and improved wellbeing can present in a variety of ways, for a far broader spectrum of technologies.

Physical, organisational and psychosocial factors are each represented at a comparable level. However, it has to be noted that they should not be compared in quantity. **Each factor, when applicable to a case study, expresses a different quality. This also explains why some factors appear on both sides of the list.** Both a decrease and increase in cognitive load have been reported, but not within the same case study. They can appear in a singular case study, in relation to different facets of the implementation. While the technology itself might reduce cognitive workload, the adjustment to a new routine and training required to use the technology can (temporarily) create cognitive overload. This stresses the importance of continuous monitoring for OSH challenges and opportunities, and the changes in OSH management this leads to.

Interestingly, most of the named OSH factors appear in context of robotic, non-embodied AI-based and hybrid systems. While there are some that are overrepresented in one type of technology (e.g. residual risk of physical injury for robotics), a considerable amount appear in most contexts. Especially organisational factors often transcend the technology barrier. The best example for this is upskilling, which was present in every case study to some extent. This is not to say that different technologies cannot come with unique challenges and opportunities, but rather that these express on a more detailed level (e.g. the extent to which task consolidation occurs at a given workplace). Knowing that the general occurrence of many of these factors is shared among different technologies can help companies move on faster from the question if they apply to them, to what expression these factors take in their case.

The most difficult challenge to overcome for OSH, based on the experiences of the companies, is psychosocial factors like the fear of job loss and negative attitude towards the systems. Not only can these be accompanied by other phenomena like decreased motivation or job satisfaction, but they can influence other facets of OSH as a result. If workers do not use the system correctly because they do not trust it, or feel like it is going to make them lose their job, they might reject using it or misuse it. The former would cost them the OSH benefits the system has to offer, and the latter might put them or other operators at risk from malfunction. Based on the companies that contributed to this project, the most reliable way to anticipate and later address these kinds of challenges is through an open, continuous dialogue with their workers, in which their concerns are taken seriously and addressed adequately. How to address the challenges and opportunities this dialogue reveals will have to be dealt with on a case-to-case basis. The presented overview can be used to support this exchange.

A key takeaway is that the combination in which the challenges and risks appear can differ greatly from application to application. A base assumption that all robotic applications will present common challenges and all AI-based systems will present common challenges should be observed with nuance. These technologies share opportunities and challenges for OSH, however, technology-independent factors like work culture can influence their expression.

Nevertheless, the overview highlights the enormous potential AI-based systems and advanced robotics have for OSH at the workplace. Especially regarding organisational factors, job transformation shows a particular density of benefits, as well as challenges. This aligns with most companies' intent to use automation to move their workers from repetitive low-skill tasks and jobs towards more supervisory roles that enable them to perform more fulfilling work. Another positive notion is that these systems can potentially increase inclusion for workers.

Understanding that OSH and factors related to it have to be considered on a long-term spectrum next to immediate health, safety and ergonomic benefits is highly important. Cobots as a tool to reduce long-term strain injuries, by reducing repetitive movement and heavy lifting, can help prevent strain injuries. This can result in older workers being able to perform their job longer, and younger workers not developing these long-term strain injuries in the first place. An ageing workforce is a development that companies in most sectors are already facing, and cobots could be one of many tools to address it.

Another factor impacted by the passage of time is the acceptance of the system by the workforce. When case studies showed that some workers had low initial acceptance for the system, based on factors like fear of job loss, or safety concerns, they also report that after using the system over a period of time acceptance in workers improves. **While education on the benefits of the system and its functions has been well received by workers, first-hand experience seemed to have the strongest positive effect in reducing aversion.** For future implementations, this could incite that workers get to come in contact with the system as early as possible, to start this process. Within standardised manufacturing there is a limit to how early worker involvement is possible, nevertheless, early and direct involvement from the start is beneficial to reduce this acclimatisation period. This could involve additional early practical trainings prior to the cobot's installation, or other forms of primary exposure, like a demonstration device in the company.

6 Recommendations

Interviewees within case studies agree on the benefits from learning based on demonstration of good practices and from the experiences and expertise of other companies. Simultaneously, they identified a concrete lack of available resources for this exact kind of information. As cobots are a comparatively new technology, with time it is expected that more European-based case studies will be publicised and the overall expertise in the area will grow. Nevertheless, knowing how beneficial it can be to collaborate with companies that have already successfully implemented cobots in their work environment, reaching out should be a step considered by those who have yet to go through the process. The following section presents selected recommendations for the implementation of AI-based systems and advanced robotics, while also focusing on enhancing OSH.

6.1 Implementation process

6.1.1 Reduce barriers, enhance drivers

When looking at the presented drivers and barriers, challenges and opportunities, once can notice that the drivers especially are coming from inside the companies and their workforce, while barriers can more often be found in external factors like legislative framework. Not all barriers and drivers apply to all case studies, nor do they comprise an exhaustive list. However, as all of them have reoccurred through multiple sectors and companies, they can be considered relevant for general consideration when trying to implement advanced robotics or an AI-based system in a workplace. Based on the companies' experiences with these barriers and drivers, one can formulate recommendations, considering how they handled them when they encountered them.

One of the most dominant drivers and barriers at the same time is worker motivation. There are some aspects to this that companies can try to influence in order to increase motivation in their work staff when it comes to the implementation of a cobot or AI-based system. While factors like an inherent affinity for technology cannot be influenced from the outside, making sure that workers are aware of the benefit a technology will have for them can be. Educating workers not only on how to use a machine but also pm how using it will benefit them (e.g. avoiding strain injuries, or providing them with more freedom over their time) is very important. This information should be included in training material the workers receive. Furthermore, some companies have found it beneficial to identify workers with special interest in the technology and provide them with specialised training and responsibilities if they wish. These workers (sometimes called 'key users' or 'technology ambassadors') can fulfil a vital social role to further raise awareness of the system's benefits as well as function as a low-threshold point of contact for their colleagues with questions and concerns. A second way to influence a worker's motivation or attitude towards the implementation is by addressing concerns about the machine. These concerns can span from the fear of job loss to concerns regarding the physical safety of the system. They should be taken seriously and addressed in sufficient form. In some cases, dealing with it on an individual level might suffice, in others a department or company-wide measure might be more efficient, especially if a larger group of workers share a concern.

The lack of available and applicable use cases and cases studies and the beneficial effect of exchange between companies and universities relate to the same underlying concept of shared information. If possible, companies should try to reach out to other parties, possibly other companies, which use similar systems to those they plan to implement to inquire about their experiences. Similarly, companies that have already successfully implemented advanced robotics or an AI-based system should consider sharing their experiences. More active research into the drivers and barriers could be done. The lack of experience is a factor that will possibly decrease over time as first-hand experiences increase. With more companies using AI-based systems and advanced robotics, other companies have more opportunities to reach out and collaborate with them. Additionally, there should be an active effort to create more, easily accessible, European case studies for companies to consult.

A diminished recommendation regarding both enhancing and inhibiting factors for the implementation of AI-based systems and advanced robotics for the automation of either cognitive or physical tasks has to do with the time component**. Underlying many more specific drivers and barriers is the lack of time available for the implementation.** This reoccurs regarding worker-related components like experience and trust, as well as the process-lengthening effect of having to navigate a novel legal landscape and familiarise oneself with new risk assessment methods. Based on the experiences of companies that have already successfully introduced cobots and AI-based systems into their workplaces, taking early initial steps and providing adequate time for effective introduction of the system can facilitate success in the long run.

6.2 AI-based systems

When integrating AI-based systems, several factors can contribute to the success or failure of the implementation. Many AI-based solutions are often custom-fit to the specific task and environment in which they perform. Companies looking to automate a task via an AI-based system should first assess the suitability of said task to be automated and the system they intend to use. While some researchers suggest that AI developers should look for ways to 'solve volatile, uncertain, complex, and ambiguous challenges'[40] via the technology, current applications are moving in a different direction. In most case studies a specifically trained algorithm provides as accurate results as possible. The systems presented in the case studies are limited in their domain of knowledge and trained on specialised indexed data. Once trained, transferring that AI-based system to a different field would be ineffective. While some address ambiguous challenges (e.g. assessing the chance for a false positive), the systems perform best in non-volatile environments with limited parameters and complexity. **They perform well in these domains and can benefit workers and OSH.** The provided examples have in common that the companies trained their systems themselves, or provided the data on which the integrator trained the system. One potential challenge with training any AI-based system can be found in the overrepresentation or underrepresentation of specific cases within the training data, which creates biased conclusions. **By creating and training on their own indexed data, companies have more control and can assess the data for bias. This does not, however, necessarily fully protect them from unconscious bias. The potential consequences of biased training data can be severe, especially if an AI is involved in processes affecting a person's wellbeing (e.g. medical decision support systems) or personal development (e.g. human resources).** In manufacturing, machine bias seems to primarily reduce efficiency. Nonetheless, any company considering the implementation

[40] Laplante et al., 2020: Artificial intelligence and critical systems: From hype to reality

of an AI-based system should either invest in checking their own training data for bias or, if the system is bought from a third party, inquire about their way of preventing bias in their training data.

Questions regarding the workers' attitudes towards AI-based systems need to be asked to facilitate a successful introduction and long-term working conditions. The fear of job loss has been acknowledged as present due to continuous automation, however, how to successfully mitigate this fear specifically for AI-based systems proves difficult to find in current literature. Within the present case studies, companies have faced the fear of job loss within their company and handled it in different ways. Noticeably, AI-based systems without a physical representation seem to trigger this fear less intensely than those that are being used in combination with, for example, a robotic arm. One possible explanation for this is that these AI-based systems have changed the working environment to a lesser extent than more traditional physical automation. Most workers who interact with these systems benefit from them in terms of a reduced workload, while their previous core task remains largely unchanged. To address concerns among workers like fear of job loss and ethical concerns about the technology, companies that report success in dealing with them have taken the approach of comprehensive education. This means they provide workers, in some cases proactively, with information about the technology, beyond the training needed to operate it. In some cases, this information is also accessible for workers who at that time do not use the technology. This additional information focuses on the advantages the system brings to the workers, how jobs are changing, and reassuring the workers that the aim of this automation is not to eliminate jobs. In addition, companies that successfully deal with concerns or resistance during the implementation process tend to have good social support within their companies. This can take the form of social counselling, anonymous feedback systems and contact personnel for any arising questions.

When it comes to automating the dull, dirty and dangerous tasks, they are often described as having high potential to be automated. When looking into which tasks to automate, it can also be useful to not only focus on these types of tasks but also on side tasks. Secondary tasks would be anything that is not a primary component of any job, but rather has to be performed by workers on the side. The example of case study ID1 is checking for forgotten tools. Performing these tasks alongside of their main task might lead to disruptions in their actual workflow. So, when looking for potential to implement an AI-based system to automate dull, dirty and dangerous tasks, companies should invest time in identifying tasks that are automatable and can potentially decrease disruptions in their workers' routine and do not make up their primary task. **While more research in this area is needed, automating secondary tasks might potentially be met with greater acceptance and might reduce negative psychosocial reactions like fear of job loss.**

It has to be highlighted that all companies are acutely aware of the complex issue relating AI-based systems and data privacy. None of the described systems record, save or analyse any person-related data, by intentional design. The systems are limited to very specific tasks, and predominantly do not come into contact with any person-related data. In the case of the gas infrastructure company, their drone technology can potentially visually 'ignore' person-related data of workers. The footage is not recorded or used to continuously train the AI. And as the drone can be used for spot inspection, it provides workers with greater privacy than a traditional full-camera system at their worksite. While loss of privacy is a highly important topic, it should not be used synonymously with AI-based systems to avoid creating negative bias towards AI applications as a whole. **The European Parliamentary Research Service, Scientific Foresight Unit report[41] recommends the full inclusion of workers and managers in all technology implementation. It contains the recommendation that data protection officers (DPOs) should not only include trade unions but also employer associations.** For workers' rights protections, DPOs should, as recommended in the new European Commission AI Act, write codes of conduct to accompany any system processing sensitive data. In the context of involving affected parties in the implementation process, companies should also communicate clearly and comprehensively what type of data the system is processing, if it is recording any data and especially person-related data, and why any potential recordings are necessary or unavoidable, before

[41] European Parliamentary Research Service, 2020: Data subjects, digital surveillance, AI and the future of work

implementing an AI-based system. This should especially not be neglected being done if the system is not recording any data, to avoid uncertainty and projection of negative presumption of users.

6.3 Advanced robotics

Advanced robotics are becoming more diverse and more companies in Europe are using these technologies. Hence, they encounter different structural and technological hurdles along the way. The implementation process can be just as diverse, with different strategies being the most efficient for different companies. Which parties are involved and to what extent not only depends on the company size but also on the level of experience with advanced technological systems. While some companies develop in-house solutions, others use third-party suppliers and customise those robots to their needs. It is therefore not goal-oriented to try and create a standard list of implementation steps to follow for every company. It can be more helpful to gather factors that helped companies along the implementation process that are not limited to their company size, sector or level of experience.

Questions regarding the introduction process and the assessment of worker attitudes towards robotic systems need to be asked to facilitate a successful introduction and human-centred long-term working conditions. All case studies acknowledged the fear of job loss due to continuous automation. They have developed ways to address these concerns with their workers and successfully reduce fear of job loss. This can be approached from two sides: by intervention and prevention. When a company becomes aware that their workers experience fear of job loss due to automation through advanced robotics or AI-based systems, certain interventions can be made. Most companies decide to improve their workers' understanding of the technology and the implications the automation has on them and their work. All case studies stress that the intention of their automation is not to destroy jobs but to improve working conditions. Educating workers on how the technology impacts and benefits them, their routine and OSH is a separate intervention form training them on how to use the system. Workers have begun to recognise that being technologically literate is essential in an increasingly digital workplace.[42] **Providing them with the skill sets needed in the long term could reduce their adjustment period to a new digital work environment and provide them with a subjective sense of job security.**[43] Preventing subjective fear of job loss entirely is likely impossible. However, companies can take preventive measures independently from the introduction of a singular system. Firstly, in cases where workers were the initiator of the automation process, acceptance was higher. This falls under the larger umbrella of worker involvement in the implementation process. Early worker involvement provides them with the opportunity to exercise some form of influence and communicate their wishes, needs and concerns early on. While not all companies might have the opportunity to involve workers in the design process of a new system, informing them about upcoming changes as early as possible, and creating a way for them to voice concerns, is good practice and might reduce fear of job loss along the way. **Having managed the subjective fear of job loss for the introduction of one kind of robotic or AI-based system does not mean a company can neglect this topic for future automation projects.**

Early worker involvement goes hand in hand with a functional communication strategy. Empirical research supports the companies' experiences that having a formal communication avenue while introducing a change initiative reduced uncertainty and enhanced commitment.[44,45] Communicating future changes to workers can reduce feelings of uncertainty towards the rationale behind the change. Furthermore, clear and direct communication has been found to promote change-supportive behaviour from workers.[46] All these findings in relevant literature were reconfirmed in the experiences of the case studies. Having both personal (e.g. team lead) and anonymous (e.g. feedback box, or via workers

[42] Smith, 2015: Technology literacy skills needed in further education and/or work: A Delphi study of high school graduates' perspectives
[43] Kozak et al., 2020: Is fear of robots stealing jobs haunting European workers? A multilevel study of automation insecurity in the EU
[44] Bordia et al., 2004: Uncertainty during organizational change: Types, consequences, and management strategies
[45] Hobman et al., 2004: Perceived dissimilarity and work group involvement: The moderating effects of group openness to diversity
[46] EU-OSHA, 2022: Cognitive automation: implications for occupational safety and health

council representative) communication systems has been described as helpful to receive worker feedback and create conversation around relevant topics.

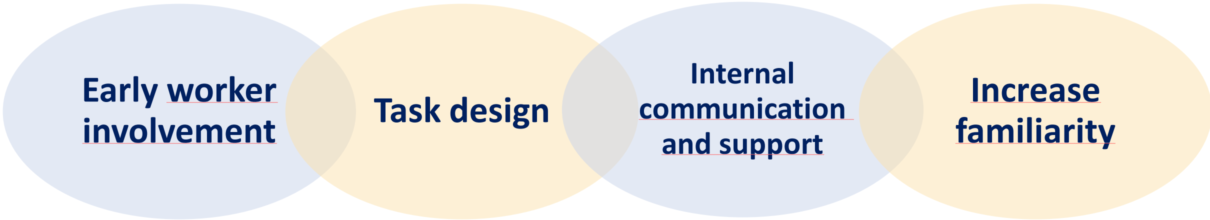
The relative novelty of advanced robotics in the workplace is accompanied by a workforce inexperienced in how to interact with them. A lack of familiarity can influence workers' attitudes towards robotic systems and colour the initial experience. Even more so, initial attitudes can be shaped by external sources like newspaper reports, which can be biased towards negative pictures regarding robotic systems at the workplace.[47] In one case study they specifically stressed how crucial it is to differentiate between fictional representation of robotic systems and the actual technology. Nomura and colleagues found that the negative attitudes towards robots decreased as experiences of interacting with them increased.[48] This is confirmed by companies, like case study (ID2), which face initial hesitance regarding the system but saw a significant reduction of this once workers gained experience with the system. Companies interested in reducing this initial hesitance could start offering early education on robotic systems, before implementing them. Furthermore, to reduce unfamiliarity in the interaction, system designers should orient themselves with established interaction design principles, one of them being the EN ISO 9241-110. The standard contains seven interaction principles for human–technology interaction called suitability for the user's tasks, self-descriptiveness, conformity with user expectations, learnability, controllability, use error robustness and user engagement. They can also be used to design and evaluate HRI.[49]

The fact that the world of work is rapidly changing, in part due to advancements in robotic systems, also increases the expectation towards workers to adapt and change with it. Working with advanced robotics often requires a new skill set and more detailed understanding of technology than most workers' previous tasks did. Some case studies have described difficulties of workers to keep up with this demand for cognitive change. New work environments can challenge cognitive abilities such as decision-making more than previous, mostly physical, tasks.[50] **For this reason, cognitive and sensorial aid should be provided to workers to prevent information overload and its negative effects on the operator.**

Lastly, several companies within the project reported a change in task structure, in relation to the implementation of a robotic system. This is mostly described as a positive change, as workers now have more time to perform their main task or are described as using the additional time to help other co-workers or perform secondary tasks. **Task design needs to be considered during the implementation process. Other companies raise the concern that workers now possibly perform more segmented tasks, decreasing task completeness. Others raise the concern that automation can lead to task consolidation and work intensification.** This risk is also described in literature relating to task design.[51] So, before implementing advanced robotics, companies need to consider what job content and tasks are left for the human worker. Tight technological coupling should be avoided, and the human should still perform meaningful tasks, not only tasks the robotic system cannot automate now.

[47] Riemer & Wischniewski, 2019: Robotics at work - News headline analysis 2016
[48] Nomura et al., 2011: Attitudes toward robots and factors influencing them
[49] Sommer et al., 2019: Interaktionsmodalitäten für die Mensch-Roboter-Interaktion – ein systematisches Review
[50] Gualtieri et al., 2020: Safety, ergonomics and efficiency in human-robot collaborative assembly: Design guidelines and requirements
[51] Karasek, 1979: Job demands, job decision latitude, and mental strain: Implications for job redesign

Figure 10: Antecedents for long-term successful implementation of advanced robotics



Technology-based factors like choosing the best-suited robotic system for the task one wants to automate are highly important for the successful implementation of advanced robotics. However, it is within their workforce and internal structures where companies report the most important steps to take to facilitate a successful, long-term implementation. Figure 10 summarises the four most often named antecedents, from the companies' perspective, for the long-term successful implementation of advanced robotics. In their collective experience, human-centred design and communication reduce or prevent hurdles along the way.

7 Conclusions

New technologies in the workplace create both challenges and opportunities for OSH. Advanced robotics and AI-based systems are no exception to that. The presented comparative report reveals similarities and differences between the 11 developed case studies and their experiences with the implementation of AI-based systems or advanced robotics, as well as their goals, motivations and experiences with OSH.

The analysis of the case studies highlighted that the commonly assumed barrier of AI being used to automate only cognitive tasks, and presents without a physical component, and robotic systems to perform only physical tasks is disappearing. Many advanced robotics incorporate AI into their working mechanisms and create hybrid systems with a wider range of capabilities. This also results in increasingly fewer challenges and opportunities being unique to only one type of technology. Nevertheless, there are still challenges and opportunities for OSH that are unique to certain types of technology. The risk of bias is uniquely associated with AI, while the risk of physical injury increases, when a physical robotic system is present. However, as mentioned above, these systems are increasingly being employed together.

The case studies have also demonstrated that most challenges for OSH can either be managed as they arise or even be prevented before they become a problem. Early OSH management during the implementation, early worker involvement, human-centred task design and clear communication are effective tools to address most issues.

It has also become apparent that many factors do not exist independently from one another but influence each other. Fear of job loss seems to be connected to the level of understanding workers have of the technology, trust in the system and the level of experience. Higher task variety can occur with decreased task completeness or a more disrupted workflow. Companies should not only consider singular facets when trying to address an OSH-related challenge in context of the technology's implementation, but also consider possibly related factors as well, to plan more targeted and efficient interventions. Furthermore, there can be benefit in looking at how even smaller automations can be used to facilitate larger organisational changes to benefit OSH.

The interviewees within the case studies indicate, and some outright predict, that there will be AI-based systems and advanced robotics in more and more workplaces in the future. **They all plan on expanding automation in their workplaces, developing new AI or improving on existing robotic systems.** It becomes more important than ever to take active steps towards making these systems as safe as possible to use, so they can benefit workers' health and safety for as long as possible.

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