ARTIFICIAL INTELLIGENCE-BASED SYSTEM FOR PRODUCT INSPECTION IN MANUFACTURING (ID3)

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 enables the removal of workers from hazardous situations and can improve the quality of work. This can be accomplished by automating cognitively strenuous tasks using an artificial intelligence (AI)-based system or by 'delegating' repetitive tasks to accurate and tireless machines like intelligent robotic systems. Some tasks might not be fully automated, but workers can still receive support through, for example, collaborative robots (cobots) operating in a shared space with workers. An increasing number of companies employ AI 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 on how they are implemented and managed in the workplace to help ensure workers' safety and health in present as well as in future applications.

EU-OSHA has developed a number of case studies with the aim of investigating 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 effective implementation of these systems.

To develop these case studies, several key informants at the EU and international levels, such as workers' representatives and industry associations representing the targeted sectors, were consulted. Initially, 16 cases were identified and preliminary information was collected through a questionnaire. Hereafter, 11 of them were further developed into cases studies, including higher levels of information collected at the workplace level.

2 Methodology

The primary data source for the case studies was interviews held with different stakeholders within companies. For each case study, up to five interviews were conducted with workers of the company from different work areas. The participants included operators, data protection officers, health and safety engineers, managers work-councillors and technology officers.

The interviews had a duration of 1-1.5 hours each and were performed in the participants' native language, if possible, or alternatively in English. The interviews were conducted using an interview guide, while the results of the interviews were anonymised.

3 General company description

The company presented here is a conglomerate focusing on a variety of sectors. It specialises in the automation and digitalisation industry, infrastructure for buildings, decentralised energy systems, mobility solutions for rail and road traffic, and medical technology. Founded more than 150 years ago in Germany, the company now has branches in over 190 countries and employs more than 300,000 workers worldwide.

This large enterprise focuses on global goals when it comes to technology and innovation. They aim to create outstanding and high-performing technology and products for their users and customers. They focus on future development and claim aiming at high standards, teamwork and sustainable practices. Furthermore, according to the company, ethical practices, integrity, and a sustainable future are respected. The company sees it as theirs and everyone's **responsibility** to comply with the **ethical industry standards**. This translates to no unethical behaviour that has the potential to put users' wellbeing at risk being acceptable within the company. They also strive for **excellence** in their services and products by addressing customers' specific needs and providing the best solutions for them. Lastly, they heavily emphasise the importance of **continuous improvement and innovation**. This not only benefits their clients but holds the potential to have a positive impact on the future in general through 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, with a variety of over 1,200 different products. Next to efficient production, the branch's secondary purpose is to provide a possible blueprint for the future of digital factories. This is achieved by in-house-developed hardware and software solutions, state-of-the-art industrial communications technology and specialised cybersecurity solutions. Within the location, a variety of different AI applications as well as advanced robotics are being used, tested and developed.

The branch predicts that in the future there will be more robots, cobots, driverless transport systems and smart manufacturing systems, not only at their location but in general. They see applications for both AI-based systems and advanced robotics in value-creating activities, logistics processes, ideal just-in-time material processes, customer delivery and human resources. Various software solutions are being studied in order to automate beyond production.

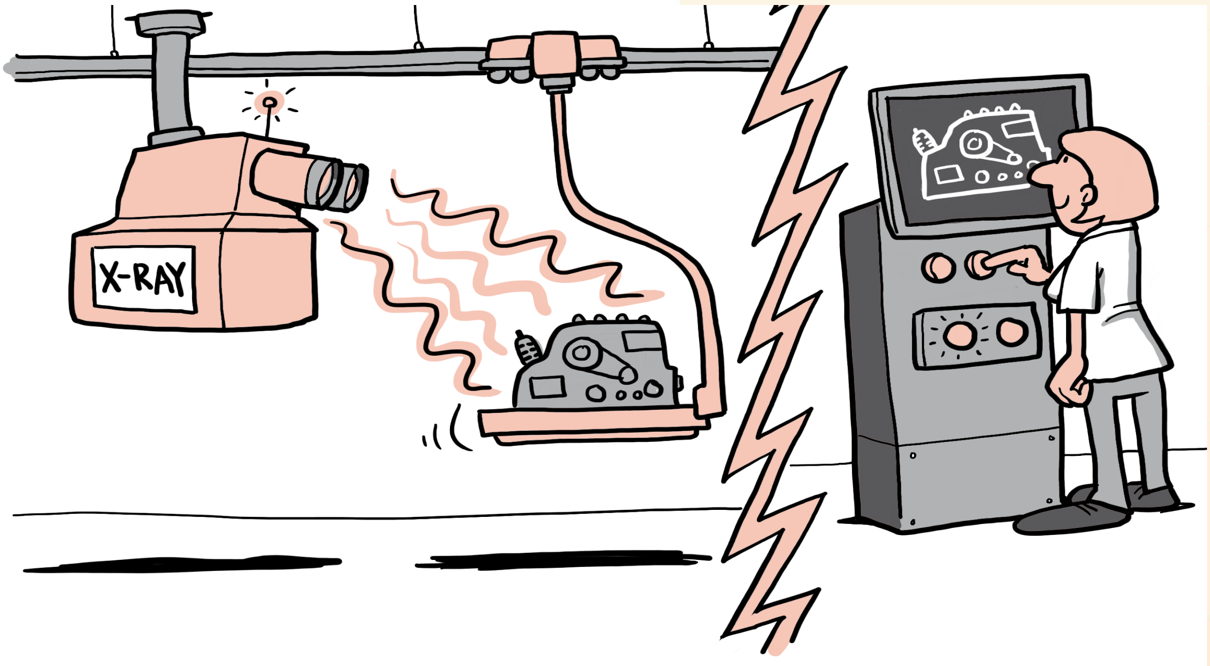
3.1 Description of the system

The branch describes AI-based systems as being used by many workers throughout process automation. The biggest area of application for AI in the company is analysing process data to optimise the manufacturing process. The primary case study of AI presented by the company is their use of it for **computer vision systems 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. Image recognition for inspection processes has been found to be very cost effective as well as accurate. An industrial camera and a PC run a system that records and evaluates several tests on **soldering points in a workpiece**. If an error is detected, the system processes the images further. Based on the X-ray images and previous data, the computer vision system **calculates whether a detected error is an actual error or a false positive**. If the algorithm determines a high likelihood for an error, the workpiece is then set aside for individual testing. If a high likelihood for a false positive is determined, there is no additional manual testing performed on the product. At a separate workstation, the worker then runs a test to confirm or dismiss the AI's assessment. While the primary error detection method via visual markers was in place before, the AI has been introduced to **reduce the rate of false positives** in this process. A false positive results in a time-intensive testing process of the workpiece. When the quality control measures have flagged an error, the worker must then begin a time-consuming process to confirm that there is no actual error in a system, which requires a high level of concentration. By reducing false positives, the worker is **relieved of this unnecessary workload**.

The company is also currently developing future applications of AI. One AI is a predictive algorithm that calculates the probability of whether an error occurs in the process or in the product, spanning over the production process.

A cartoon-style representation of the system, performed tasks and interaction with workers, including some of the challenges and opportunities for OSH is presented in Figure 1.

Figure 1. Artificial intelligence-based system for product inspection in manufacturing



3.2 Taxonomy-based categorisation

To categorise different types of technology, a taxonomy specific for different important criteria of AI-based systems and advanced robotics was developed by EU-OSHA.[1] This taxonomy includes, among others, the types of backend and frontend being used and the type of task performed, as well as which category it falls under (information-related, person-related or object-related). It 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.

Figure 2: Taxonomy for AI-based systems and advanced robotics for the automation of tasks

According to the taxonomy developed for this study, the AI-based system performs a **cognitive task** with an **AI backend software**. The task itself is **object-related**, as well as **repetitive**; however, there is **no physical manipulation of the workpiece**. The AI is a predictive algorithm that draws data from image analysis as well as previous production data. The system itself does not have visual input but is supplied this data by a foregoing program. The system **assists** the worker by estimating a false positive in a workpiece. The worker still performs the entire inspection on the workpiece that contain errors; however, the AI optimises the workload

[1] 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*, 2022. 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

overall. The OSH dimension, which is affected by the AI-based system, is **psychosocial**; more precisely, **cognitive**.

While the interviewees reported that smaller AI-based applications are used in a variety of office workplaces throughout the company, the AI examined in this case study impacts production jobs, specifically end-product inspectors. As outlined before, their **general work activities** do not change due to the AI, but rather that the quantity and pace of work changes. By reducing false positives through AI use, fewer inspections need to be performed.

Interestingly, on **the management level**, introducing AI has changed managers' work routines as well. While not directly interacting with this specific AI, the interviewees reported that the planning process for production has changed massively, since both AI and robotic systems are considerable options. They observe a transformation from a manual to automated workplace. This includes new challenges and opportunities for planning and management that were previously unavailable. Previously, planning prioritised maximum feasibility under given time constraints; today, they prioritise value stream-oriented, short distance and quick implementation planning. Learning about and considering these new options has changed work on this level, while not directly working with the AI in question.

So while the primary user's **job content and routine** in this case study has not undergone considerable changes**,** other workers in the company have had to adapt, due to the technology. The primary user did have to undergo special training when the AI was introduced in the workplace; however, this was a temporary change in routine.

4 Implementation process

A key factor for the successful integration of technology into a new work 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, some of the most important steps are the assessment of whether the intended goals have been reached, documentation of what challenges were faced, and finally consideration of 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

Setting **goals** prior to implementing a technology can help in quantifying the success of the implementation and also inform what kind of technology is needed to reach them. The interviewees expressed a number of objectives and goals for the introduction of the AI. The primary goals were either production- or personnel-oriented.

The need for an increase in production, cost reduction, flexibility of production and 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. Introducing AI and robots was also described as making the business future-proof. In addition to these goals, increasing workers' qualifications and further training those who already worked for the company was listed. From the works council's perspective, preparing workers for future jobs is of high importance.

More generally, when introducing a new technology, both workers councils and management expect and intend for it benefit the workers' wellbeing. The system implemented in this case study aimed at reducing false positive inspections, which would optimise workers' workload and reduce cognitive overload, as the task demands concentration and attention to detail. Based on the initial experience with the system, these goals seem to be achievable once routine has set in.

While the interviewees reported that the company had already achieved significant goals, they also highlighted that automation is an ongoing process and that there are still gaps that need to be filled. The impact of certain measures can only be evaluated over time, if at all. While an increase in production and output was quantifiable, how well adjusted both workers and the production line are in terms of future developments will only become clearer after some time has passed.

4.2 Implementation

Before a new technology can be introduced into a workplace, there are a variety of factors to consider and often several stakeholders to involve. The implementation process can differ from company to company. With AI-based systems and advanced robotics being so customisable in their application, the general implementation is going to be different for each case study. Nonetheless, there can be common implementation steps taken, with regard to who is involved in the process. The standards considered to implement a technology are equally important, both with regard to which are widely used and which are relevant to a specific case study. Furthermore, the individual difficulties and challenges are as vital to understanding the success of a case study as the ones more broadly shared among several case studies.

For this case study, the first step is symbolised by a new impulse for change. Based on this, a project team is created, a concept developed and after an approval process, simulations are developed. Safety assessment and cost estimates are obtained and after a final round of approval set up is initiated. This includes acceptance tests and real-time functionality tests. If the test runs are successful, it can start operating.

4.2.1 Implementation steps

To implement a new technology in this company, an introduction process is followed in which all stakeholders relevant to a project were defined and involved. Usually, this impulse for implementation can come from any worker in the company. If workers identify a potential for automation at a specific workplace, they can communicate this to a supervisor who initiates further assessment. Based on this, a project team is created, including a project planner, a workers council officer and onsite data protection officer, workers as well as advisory security staff. Based on the specific need identified by the impulse, a concept is developed. As this case study was capable of developing its own technological solutions, the project team then decided whether to develop externally or internally. Final approval of this solution must be given by the project planner for construction to begin. Based on the presented solution, simulations and possibly a test set up in a laboratory environment are created. An initial safety assessment of the worksite is carried out and cost estimates are obtained. If everything is approved, management agrees that the relevant parts can be ordered (self-produced or, in the case of software, be bought or developed). The next step is the set-up of the technology at the actual workplace. This is followed by a preliminary factory acceptance test. If no need for change is identified at this stage, the system set-up is finalised and further test runs are carried out. Physical systems undergo real acceptance test, in which relevant functions are tested under real conditions. This also includes further onsite risk assessment to ensure occupational safety. Finally, before workers operate the system, training courses are provided to them. This is to ensure they can use the technology safely and efficiently. Once the system is operational and fully rolled out, it becomes an essential part of the work process and **mandatory** to use, as the products and the production are optimised.

4.2.2 Standards and regulations

The task of ensuring that all relevant and applicable mandatory standards and regulations are considered during development and upheld during implantation and use falls under the jurisdiction of the companies' occupational safety officers. The **German general data protection regulation** (DSGVO) is always considered when an AI-based system is introduced to a workplace. Should there be a question regarding data privacy, the company always decides in favour of the person concerned. Furthermore, the **German IT baseline protection** (IT-Grundschutz) and the letters from **Digitalcourage**[2] are consulted. These external sources frame the **internal standards** the company has set for itself as well as the thorough consideration of current German and **European jurisdictions**. As the company has several locations, they also consult advisory recommendations from within the company through other locations that share their experiences. Beyond official standards, regulations and internal guidelines, the company works closely with universities when it comes to the development of new AI-based systems. Publications with explicit recommendations are especially included in their implementation process.

4.2.3 Difficulties and challenges during implementation

Implementing a new AI-based system comes with a set of challenges. AI is considered by many to be uncharted territory. There is a **lack of experience** with every stakeholder involved, compared to more established technologies. It is new for the workers council, as there is **no routine** in assessing the impact of AI-based systems yet, which increases the amount of **bureaucracy**. This can potentially slow down the introduction process. Additionally, the operators need to be taught what the technology is capable of, as it is very unfamiliar. Acquiring these kinds of **new skills** can be a time-intensive process and demands high learning capabilities from the operators. However, these difficulties are likely to decrease as experience grows, to the point that introducing an AI-based system will become like most other new technology introductions.

4.3 Worker involvement

Worker involvement during the implementation process can contribute to the success of a technology's implementation. 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

[2] See: https://digitalcourage.de

can be involved, companies seeking to introduce AI-based systems should consider at what stage worker input can be included.

Worker involvement during implementation starts after the concept phase has been successfully completed. During the system's introduction phase to the actual workplace, workers are routinely involved. Involving them as early as conceptually possible intends to let them get to know the future system and opens up the possibility to collect feedback. Workers are encouraged to be an active part of finding solutions at the workplace. However, working on the project at this early stage is voluntary. This path of early involvement has proven to be effective in a number of ways. Firstly, it seems to increase the acceptance of the technology once it is fully integrated. Secondly, workers with a high affinity for technology and innovation can be identified.

The operators of a new system are also present when the system is checked for safety and can give active feedback and veto rights. However, their involvement does not end with the final roll-out but continues into the ongoing production. The workers are trained to optimise the system, hence there is a continuous open feedback system for them to be involved and submit suggestions for changes, optimisation or innovation.

4.3.1 Training and worker qualifications

Worker training and education is a major element for the success of technology implementation.[3,4] One of the concerns when it comes to the automation of tasks through AI-based and robotic systems is the process of deskilling. Automation like this is generally seen as a starting point for one of three skill developments: **deskilling, reskilling or upskilling**. Using the AI-based systems does not lead to a situation where workers no longer perform the task, but rather do so in a less frequent and more concentrated way. Therefore, workers will most likely not experience a loss of skill as they still have to perform the task once the system has detected an error. However, it could be rather challenging for inexperienced workers to acquire this skill.

All interviewees stressed that training the workers and maintaining their skills and experience within the company is one of the highest priorities. The company aims to preserve jobs through automation, not to eliminate them. Hence, they prioritise upskilling and reskilling under the company's core value of **lifelong learning**.

The provided training is tailored to the specific knowledge needed to perform the new or changed task. Training tends to be more intensive for robotic automations, compared to the AI-based system for cognitive automation in this case study. As operators still perform the same task as before, they have less need for reskilling.

As AI-based systems become more widespread in the company, the job groups with the highest need for additional training are the system maintenance teams. Continuous training is a prerequisite for the proper maintenance of the system in the long run.

All operators are trained in handling **emergencies and unexpected situations should they arise**. This is a fundamental part of all training provided for a new technology. Every system always has the option for an emergency stop, in addition to planned stops. While the system is designed to be safe during everyday production, preparing workers for unexpected situations, and equipping them with the necessary knowledge and tools to handle these, is vital for the overarching safety of the worker.

4.3.2 Feedback system and report handling

The company in this case study values **constructive and continuous feedback** from their workers. Suggestions that are brought forward by workers to change the workplace by introducing a new tool, technology or AI-based system are received and evaluated for their feasibility. Especially during the introduction process, worker feedback is **requested and encouraged**. Involving the worker early in the process helps to reduce negative feedback in the long run. One way of collecting this feedback is a digital improvement suggestion system, in which each project has its own **surveys** and **feedback box**. This also encourages any feedback regarding OSH concerns from the workers.

The feedback about the AI-supported X-ray systems in this case study has so far been positive. Their use has resulted in a reduction in workload as well as a decrease in unnecessary work steps, freeing up workers' time, which can now be dedicated to other tasks.

For more general feedback, the company provides direct persons of contact for workers. These can be their supervisors or representatives of the workers council. Should a worker be uncertain of whom to contact with their specific feedback, there are community networks available to help identify the relevant person.

[3] Waldeck, N. E. (2000). *Advanced manufacturing technologies and workforce development*. Garland Press.

[4] Fraser, K., Harris, K., & Luong, L. (2007). Improving the implementation effectiveness of cellular manufacturing: A comprehensive framework for practitioners. *International Journal of Production Research, 45*(24), 5835-5856. https://doi.org/10.1080/00207540601159516

4.3.3 Level of trust and control

An adequate level of human trust towards the interacting system promotes appropriate system use,[5,6] while extreme forms of trust can lead to adverse effects, such as automation complacency,[7] and insufficient trust may lead to neglect of the technology.

Involving the workers early on in the introduction process has proven to have a positive effect on their acceptance of the system for this company. Providing **information early** on and communicating clearly is vital. They are aware that trust only **develops over time**. After a longer period of use, trust in the machine increases and one can assess it accurately. However, this can also happen with distrust. A valuable lesson learned by the company is that if there is no **transparency** and the workers do not have a positive attitude towards the automation, resistance can increase.

In addition to trusting the system, the **level of control** that a worker has can significantly influence a number of factors. For this case study, the level of control the operators have over the AI-based system and their workplace in general has not significantly changed. Any customisations to the system require a specialised technology expert, who has both the knowledge and permission to perform adjustments. It can be that the operator has this qualification, however, not every operator doubles in this function.

The most noticeable change after implementing the AI system has been the operators' control over their time. As the system reduces false positives and thereby the number of overall inspections, the worker has more time that they can spend on other tasks. This effect has been reported back as a positive development at the workplace, via the company's feedback systems.

4.3.4 Company culture and structure

The changes that automations via AI-based systems can bring to a workplace can impact both company culture and social structures. The extent of this differs from system to system and company to company, however, it is an effect that should not be overlooked. Regarding the AI-based system in this case study, no changes to the company culture or structure were named. The interviewees report an underlying positive mood and openness towards automation and digitalisation, based on the lived positive experiences.

Regarding newer, innovative systems in general, not only AI-based systems, it is also part of the company's culture to have cross-site meetings, to exchange experiences, and continuously develop new ideas and be up to date on any relevant changes in other locations.

The company operates under the core belief of **lifelong learning**. This is ingrained in the company's culture and surfaces in a number of ways, relevant to the automation of tasks via AI-based systems. They offer digital driving licences, training courses on the use of robots, and training and information events for everyone in the company. Every worker can partake in this training, regardless if they work with an AI or robotic system. The specific location in which the case study is implemented also possesses digital education facilities. There, these theoretical and practical training courses are held, and selected technologies are on display and can be tried out. This is intentional so that barriers are broken down and everyone is included in the development of the company.

In the larger context of digitalisation, the interviewees observed a shift towards **flatter hierarchies** in the social interaction between workers. The perception of supervisors and management shifts away from a position of supervision towards a perception of them as coaches.

Within scientific literature, concerns of social isolation and job loss are among some named negative impacts of automation. Companies might opt to provide additional support for workers who interact with the system or have other kinds of concerns.

While this company does not provide specialised support targeted at operators of AI-based systems, they do provide a variety of social support structures for all workers. There is social counselling and the workers council to deal with workers' worries and needs. This specifically aims to **reduce anxiety** and worry regarding all concerns, including fear of job loss. Fear of job loss does occur in workers, and when brought up it is addressed and worked through. The company has offered public 'question and answer' sessions in which everyone can participate. Concerns are brought up and one way of trying to reduce them is conveying what the advantages

[5] Parasuraman, R., & Riley, V. (1997). Humans and automation: Use, misuse, disuse, abuse. *Human Factors, 39*(2), 230-253. https://doi.org/10.1518/001872097778543886

[6] Hancock, P. A., Kessler, T. T., Kaplan, A. D., Brill, J. C., & Szalma, J. L. (2020). Evolving trust in robots: Specification through sequential and comparative meta-analyses. *Human Factors, 63*(7), 1196-1229. https://doi.org/10.1177/0018720820922080

[7] Parasuraman, R., & Manzey, D. H. (2010). Complacency and bias in human use of automation: An attentional integration. *Human Factors, 52*(3), 381-410. https://doi.org/10.1177/0018720810376055

of the systems are, how jobs are changing and reassuring the workers that the aim is not to eliminate jobs. These measures have had a positive impact on the acceptance of innovative systems in the company.

Furthermore, specialised personnel in the workers council take on the role of **confidants**. These people assume the position of a mediator, should a worker wish to address concerns not via the official channels.

4.4 Future developments

Innovation and future-oriented decision-making is associated with great significance for the management positions in this case study. Looking back at the company's long history of continuous automation and innovation, as well as research, this case study firmly evidences their efforts and developments towards more innovative automation in the future. There are also future applications of AI that the company is currently developing. One is a predictive algorithm that calculates a probability of whether an error occurs in the process or in the product, spanning over the production process. For legal reasons, the exact specifications of future AI-oriented projects could not be shared in detail. However, they emphasise **logistics processes** and **ideal just-in-time material processes**. Beyond production automation, **human resources** are looked at in terms of software solutions to automate and improve the process. One interviewee predicted that in the future, every worker, including both office and production workers, will be supported through some form of AI-based system. Some of these will involve robotic solutions in production.

5 OSH impact

The introduction of an AI-based system or a collaborative robot can have a wide impact on OSH. It can pose a number of 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. These new forms of task automation can even lead to changes in the overall OSH management of a company. Through the interviews, a number of these factors for this specific case study have been identified and discussed.

5.1 Challenges

As advanced robotics and AI-based systems allow highly individualised solutions for a company, they might also present challenges specific to their use. In addition, more universal challenges can emerge, which the company then has to address. The interviews contained a number of OSH challenges the company had to face, both during the implementation phase and in ongoing production.

One phenomenon related to the automation of tasks via AI-based systems can be interpreted as both a challenge and an opportunity. The technologies are becoming increasingly **customisable**. System developers have to decide if a technology should be implemented on the basis of the average worker working with said technology or if there are groups of workers who need more individualised solutions. The difficulty resides in deciding how to proceed, as both have different outcomes when it comes to both economic and OSH-related considerations. Weighing the **safety advantages** of a continuous system and the predictability this brings to a workplace against the possible **ergonomic benefits** of a custom solution, while operating under **economic restrictions**, can be challenging from a management point of view.

5.1.1 Qualification

One challenge reported is the increasing need for workers with higher qualifications. While previously there were work activities that could be taught to unqualified staff and learned through minimal training, this is now less possible. While the company provides a variety of training sessions and upskilling opportunities to its workers, they still face a **shortage of specialised personnel**.

5.1.2 Cognitive overload

The increasing digitalisation and the continuous training, acquisition of new skills and changes in work routines have led to an increased cognitive load and demand for cognitive flexibility on workers. This has been a challenge for workers with lower affinity for technology. While the willingness to learn has reportedly been high, there has been feedback that this development is challenging for some workers.

5.1.3 Fear of job loss

A general fear of job loss in the context of task automation has been reported in this case study as well. While it did not specifically originate from the AI-based X-ray systems and its operators, it cannot be ruled out that it still related to it. While the operators at that workstation continue their work comparatively similar to before, fear of job loss can still be present in the larger context.

The company has taken **several measures** to address and reduce this fear in workers with reportedly good success rates, however, they are aware that this fear could resurface when new technologies are introduced.

5.1.4 Unpredictability

In theory, **self-learning systems** have the ability to change their behaviour based on new input data, and thereby exhibit unpredictable behaviour, to a certain degree. In this specific case study, the AI does not modify its behaviour but **simply improves its precision regarding fault detection**. It will not exhibit a new type of behaviour, or a changed way of displaying its results. Hence, unpredictability is not a specific OSH concern within this case study. However, the technical engineer specialising in AI solutions remarked that in the future and with possibly more complex AI-based systems in the workplace, unpredictability should be considered when doing risk assessments, as well as during training of the operators. It could lead to malfunctions in the system if a worker is not fully aware of the system and how it operates.

5.1.5 Workers groups

There were **no specific high-risk groups** named regarding the X-ray system. More generally, the task cannot be performed by workers with specific disabilities (such as blindness, or wheelchair users), as it involves visual inspection and handling of large workpieces. However, collectively the company works in close collaboration with their representative body for disabled workers to **increase accessibility** in the workplace, looking for individual solutions where it seems feasible.

Specifically in this case study, only **untrained personnel** were mentioned as a risk group, but primarily in the sense that their lack of familiarity with the use of the system exposes them to higher risks, and not the system itself.

5.1.6 Demographic changes

Related to the challenges in the area of worker qualifications, the demographic shift in the workforce also poses a challenge. This expresses itself in the shortage of new workers with the needed qualifications. Furthermore, older workers report more challenges adapting to the changes in the workplace and high demand for new skill acquisition. While the company is addressing these issues with training and upskilling measures, this does not address the underlying societal development.

5.2 Opportunities

The introduction of the AI-based system to the production site also held numerous OSH benefits and opportunities.

5.2.1 Screen time reduction

Prior to installing the AI-based X-ray system, the worker had to spend considerably more time inspecting the workpieces on a screen. Now, their screen time overall has been reduced, and they have more frequent breaks in between. This has led to a positive effect on their **wellbeing and concentration** and has also led to a **reduction in errors**.

5.2.2 Mental workload

The automated visual inspection task is especially cognitively demanding. It requires consistent concentration as well as a high level of attention to detail. Ratings of quality, in particular, can be incredibly mentally tiring. This is very straining for both the mechanical element of the eye and the mental load. As the system **reduces the number of cases** the worker has to inspect, it improves mental strain and optimises the workload the workers experience throughout the day.

5.2.3 Task variety

As the workers working with the AI-based X-ray system experience a decrease in inspection tasks, they reported more time free to allocate to other tasks. Hence, the system has the potential to expand the **task variety** the worker performs, in addition to their main tasks.

5.2.4 Wellbeing

The opportunity to increase overall wellbeing was also named in the context of task automation and the use of AI-based systems and advanced robotics in general. Many different solutions offer the opportunity to create a workplace that is more ergonomic, less stressful and less physically straining. These things can improve a worker's wellbeing.

5.2.5 Social interaction

The more widespread introduction of AI-based and robotic systems has been attributed to a positive social change within the company. Especially regarding the relationship of workers towards their managers and supervisors, a flattening of hierarchy is reported. The perceived role of the supervisors has shifted. While previously in a more authoritative position, they are now seen as coaches for the workers, leading to more relaxed interactions.

5.3 Barriers and drivers

Many companies go through the process of integrating advanced robotics or AI-based systems into their workspaces for the first time. The present case study encountered a variety of barriers and drivers throughout this process. Identifying these can help this company as well as others avoid barriers and promote drivers for their process automation.

The factory in this case study already went through the process of integrating both AI-based systems and robotic systems a number of times before. Throughout these experiences, a number of reoccurring factors were observed.

5.3.1 Barriers

A barrier related specifically to the automation of tasks through an AI-based system is the overall **lack of experience** with the technology and related processes. This can result in the implementation process being slowed down considerably. Currently, the process also results in a considerable amount of **bureaucracy**, which can lead to further delay. While this is not a barrier that specifically impacts OSH, it can impact the overall success of the implementation. Especially given that companies have to consider financial feasibility, delays might result in certain projects not being completed, and, hence, workers not experiencing the benefits of such systems sooner.

5.3.2 Drivers

Based on the experience with task automation through AI-based systems, this case study has identified three major drivers that contribute to the success of these types of projects.

The primary, and repeatedly named, driver is **early worker involvement**. For this company, this goes as far as providing access, information and training on processes related to digitalisation, AI-based systems and advanced robotics, regardless of job position. This early worker engagement has led to an increase in acceptance for new systems, and an overall positive attitude towards the subject of task automation.

On a company level, they also name clear and open **communication** between all involved parties as a necessity for successful system implementation. This includes the above-mentioned early involvement, but also the active encouragement of feedback, as well as the option to provide anonymous feedback from the workers’ side.

The third driver is the **collaboration** between other companies, other firm locations and external parties, such as universities. Universities show great interest in new technologies. The younger generation is especially more involved and drives innovation. This collaboration helps to keep up to date with the most recent technological developments, but it also allows all parties involved to learn from each other’s experiences, successes and failures.

5.4 OSH management

New technology can lead to a change in work procedure. This also includes OSH, the expectations placed in the technology and subsequent OSH management. The interviewees highlighted that OSH is a major motivator for change in their workplaces, to the point that they have implemented systems to primarily increase ergonomics, not economics.

5.4.1 Expectations for OSH

When introducing a new technology into a workplace, the workers council highlights that there is the expectation that it will benefit the workers’ wellbeing. This is supported from a management perspective to the point that an **ergonomic improvement** is less of an expectation and more of a requirement. The interviewees highlighted that ergonomic considerations are already fundamental components of their workplace design process, however, new technologies, like the X-ray vision system, allow for continuous improvement.

In this sense, the OSH expectation for the X-ray vision system was an improvement of the workplace ergonomics, which have been met in the form of screen time reduction, optimised workload and more freedom of time allocation during the workday.

5.4.2 Emerging OSH risks and monitoring

Considering that the X-ray system has only recently been introduced to the company, the time to identify new, emerging OSH risks has been very short. To this point, no unexpected OSH-related consequences were identified.

In general, the company does continue to look out for arising problems and complications, including OSH-related developments. When any need for readjustment is brought forward, the necessary steps are taken to ensure the workers' safety. For other systems, this has included installing more sensors or introducing safety barriers. Every incident or close call is documented and assessed. If the assessment results in a need for action, steps are taken to prevent reoccurrences.

5.4.3 Communication strategies

The strategies the company uses to communicate internally did not need to be adapted when the AI-based system was introduced. They continued using the established communication system, including the **feedback loop** during technology implementation. For every new project, a project lead is publicly known, who can be approached with anything relevant to the project, including OSH concerns. As soon as there is a problem related to safety, it must be **reported directly** to the manager, who reports it to everyone involved and responsible. Depending on the type and scope of the problem, the response will be timely.

Any major changes or modifications to the system are communicated directly to the operator, prior to implementation, but after testing has been finished. The only exception are basic software updates that do not directly affect the worker. In these cases, the operator will be informed after the update. If the change has an impact on occupational safety, this happens as part of a special instruction. If there are changes to the workflow or work process, this will be taken into account in the work instructions and the worker will be informed prior to working on the updated system.

The **health and safety department must be included** for any changes to the system, even if it is a minor change. It is checked and, if approved, implemented and communicated accordingly. Particular attention is paid to informing the workers when the impulse for change came from them. This helps workers stay aware that their input is heard, valued and implemented.

The increased use of AI has also led to more exchanges with **universities** and international partners. The universities actively contribute to the implementation and show great interest in new technologies. Having open, frequent and continued communication with universities and partners has been beneficial to all parties involved.

5.4.4 Organisational and social impact

The rising importance of data processing when it comes to AI-based systems has created a new team of business and IT experts within the company. They specialise in the development and upkeep of the systems used in the company.

Introducing more AI-based systems has changed the discourse between workers. There is reportedly a lot of talk about the systems and the topic of automation. AI is becoming more prevalent in everyday work. Throughout the process of automating and digitalising more tasks in the plant, the perceived social hierarchy has also flattened. However, the X-ray system alone has not had a noticeable direct impact on the social structure within the plant.

The overall digitalisation through production has decreased the number of people working bound to cycle times. This has resulted in less communal breaks, as they are not predetermined by cycle times anymore; however, it has also increased workers' control over their time allocation. In total, the social interaction between workers did not seem to decrease.

5.4.5 Integration of OSH management

When it comes to managing OSH risks, the company has a threefold approach. During the design and implementation phase, a risk assessment is performed to classify and address as soon as a relevant threshold is exceeded. The measure then taken is highly dependent on the system. It can be a fence, personal protective equipment or an organisational action in the form of training.

A second factor in managing OSH risks is a clear assignment of roles. Only qualified personnel are allowed to interact with a system. Operators are qualified to use a system, but not necessarily to make any changes. Changes are performed by trained technology experts only.

Any remaining risks are made visible and, should new risks be identified, they are evaluated to prevent any further impairment of the workers. In case of acute danger, the system is shut down immediately, in accordance with the set safety standards.

The AI-based system in this case study has not led to any significant changes in OSH management. In the pilot phase, the team leaders were informed early on when onsite testing should be started, so that a favourable time for application can be set. The system and the workplace were assessed for any additional risks, with a specific focus on data protection. However, as the system does not collect any person-related data, or capture a worker on camera, neither of these concerns needed to be addressed in a specialised way. As more AI-based systems were starting to be introduced in the company, the company underwent a general change in handling the implementation process first needing to acquire the specialised knowledge regarding topics like privacy protection. This is still an **ongoing process**, as it has not become routine yet and therefore is still a comparatively slow, bureaucratic process.

5.4.6 Need for action

There are several different stakeholders and actors involved during the implementation process of a new AI-based system. These were internal (for example, management, technology experts, workers council members) or external actors, like other companies and legislation. As the company in this case study identified earlier, good internal communication and external cooperation can be vital factors in the success of adopting new technology. Hence, it is also important to identify possible needs for action from any stakeholder involved. The interviewees did not name any areas where there was urgent need for action regarding OSH. On the contrary, they pointed out that there are very detailed guidelines to address AI-specific safety concerns like data privacy. From the management side, there is an increased need to offer **more training** to make digitalisation easier. They wish to encourage workers to independently make suggestions as to which processes can be automated and so on. From the workers council perspective, there is a continuous need upheld that any changes to the workplace, be it AI-based systems or robotic systems, must be designed in such a way as to be beneficial to the worker.

While most of these needs for action were not specifically targeted towards AI-based systems alone, but rather the larger process of digitalisation, they should still be considered when approaching AI-based solutions, as workplaces become more interconnected and continuously digitised.

5.4.7 Cybersecurity

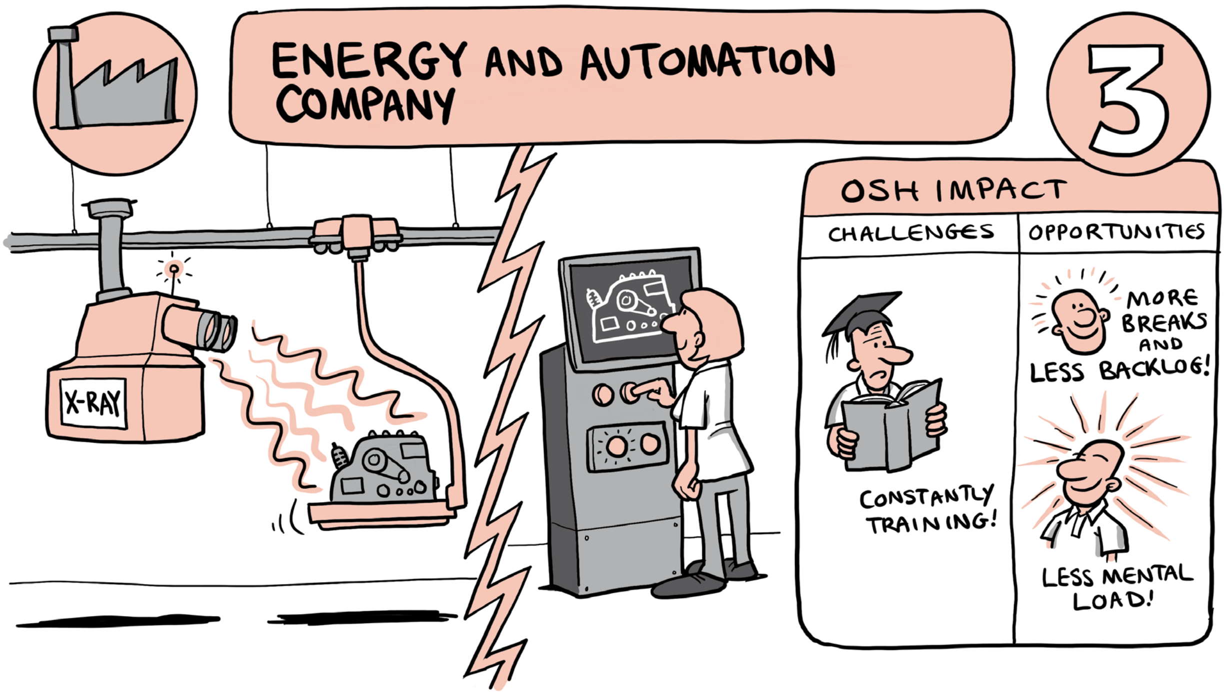
With technology becoming increasingly interconnected and data being a resource needed by some AI-based systems to improve their functionality, the topic of cybersecurity becomes prevalent in companies employing these technologies. The way that cybersecurity is handled at a company level is a key factor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

As mentioned above, in the section regarding the consulted standards, guidelines and regulations, both data privacy and cybersecurity are highly important to this case study. There is a **detailed data security concept**. It includes that as soon as there is a chance that personal data could be collected, this **data will be blocked**. Especially any workplace with a camera system is **evaluated for data privacy** and special attention is paid to it so that there is no worker on the camera feed. If it is absolutely unavoidable, the workers are informed in detail prior to working in that area. Regarding their data privacy, the company's own internal regulations are stricter than those specified by the German legislators.

For this specific case study, no additional measures in regard to cybersecurity or data protections were taken that would not be covered by the default measures. The **system does not collect any personal data**. With regard to cybersecurity, it is subject to the same protection measures as other parts of the production.

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

Figure 3. Artificial intelligence-based system for product inspection posing challenges and opportunities for OSH



6 Key takeaways

There are a number of key takeaways from the company's use of AI at the workplace. The AI **does not fully automate a task previously performed by a human worker**, but its involvement significantly optimises their workload. The worker's task does not change, but they have to perform it less frequently, have more control over their time and reduce their screen time. With mentally demanding tasks such as quality control and error inspection, this automation can have a positive effect not only on the subsequent error quota but also more importantly on the **wellbeing** of the worker.

A repeated and fundamental success factor for implementing any changes in the workplace, including AI-based systems, is **early and extensive worker involvement**. This begins with the fact that the impulse for changes at a workplace can be brought forward by the workers themselves. This comes full circle, when the company pays attention to informing workers when it was their impulse that ignited a change. In addition, the worker involvement goes beyond singular case studies. By providing access to, information about and training on processes related to digitalisation, AI-based systems and advanced robotics, regardless of a worker's job position, they gain the ability to be up to date and informed about technological developments overall. This reduces adversity towards technology and helps mitigate fears towards the AI-based systems.

The worker involvement goes in tandem with a clear bidirectional **communication strategy**. This involves the explicit encouragement of feedback, both general and project-specific. It also covers several internal networks to either identify the stakeholder who needs to be addressed with feedback, as well as the possibility to connect with other workers, or the workers council for any concern.

Another valuable takeaway from this case study is the importance of the **education and training** of workers. Especially given that the industry is facing a growing shortage of qualified personnel, focusing on upskilling existing workers becomes a vital step to future-proof the company. However, this process has to be balanced with the simultaneous rising demand for the ability to constantly learn and adapt to new tasks, environments or machinery. Improper approaches to this can lead to excessive stress or cognitive overload on the workers. So, training provided to workers has to be conscious of this balance.

Finally, the importance of **collaboration** between different stakeholders should not be understated. This extends from other company locations, should a company have them, to universities and other companies. Exchanging experiences and benefitting from others' experiences with implementing AI-based systems is a beneficial process for all parties involved. Especially as lack of experience has been identified as a barrier in the field, reducing this by involving parties with more experience can support the successful and timely implementation of more AI-based systems in the workplace.

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