CASE STUDY

# COLLABORATIVE ROBOT LIFTING PARTS IN AN AUTOMOTIVE AND INDUSTRIAL SUPPLIER (ID1)

## 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 cases 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 Slovenian-founded company operates on a global scale in the field of automotive and industrial technologies. The company is a developer and supplier of state-of-the-art systems for industrial technology and electrical engineering. To this end, they use a variety of modern technologies, including advanced robotics. Founded in the 1950s as a spark plug production facility, they have since expanded their production repertoire and location portfolio, with commercial locations in **over 55 countries**. Within Slovenia, they employ **around 1,700 workers** in their production sites.

Their objective is to provide customised solutions for automotive and industrial applications. This business goal is accompanied by a number of core values both towards external stakeholders and their own personnel. The company’s business philosophy emphasises acting responsibly towards their suppliers, local communities and the environment. This is achieved by creating long-term cooperations that foster mutual growth, support local public life and reduce harmful emissions. Beyond their focus on working responsibly and innovatively with their clients, the company has a strong worker-oriented focus in their core values.

The company focuses heavily on its **corporate culture**, in which both innovation and technological excellence are championed. Furthermore, they support the professional and personal development of their own workers and highlight the importance of innovative and resourceful thinking.

The company attaches great importance to the development of the workforce and aims to create a working environment in which both good relations and personal development are fostered. This goes in tandem with their ongoing efforts to reduce the risk of workplace injuries, long-term health problems and non-ergonomic positions. Also, the company recognises the responsibility to customers and suppliers as well as local communities as being a trusted entity that practices social responsibility and continuously improves its conduct. In addition, acts within an environmental agenda to be energy efficient and reduce its emissions.

They focus on developing workers' competencies through regular internal and external training**. Reducing the risk of workplace-related injuries and health issues as well as providing a safe and healthy environment for their workers is strongly emphasised** in their workplace philosophy and design. They also use innovative technology to support this effort. The robotic system presented in this case study is one of the many innovative technologies used, intended not only to increase productivity, but also worker safety.

In the past, the company introduced robotic systems to their production cycle, which focused on fully automating specific stamping tasks. This high-precision task, which simultaneously is highly repetitive, was deemed suitable for automation through robotic systems. More recently, they have also introduced a cobot into one production line that specialises in lifting parts between production steps. However, in this case, a worker would still need to perform an additional check before the part can be processed further. Hence, the company decided to introduce a cobot, suitable for sharing a workspace with a worker.

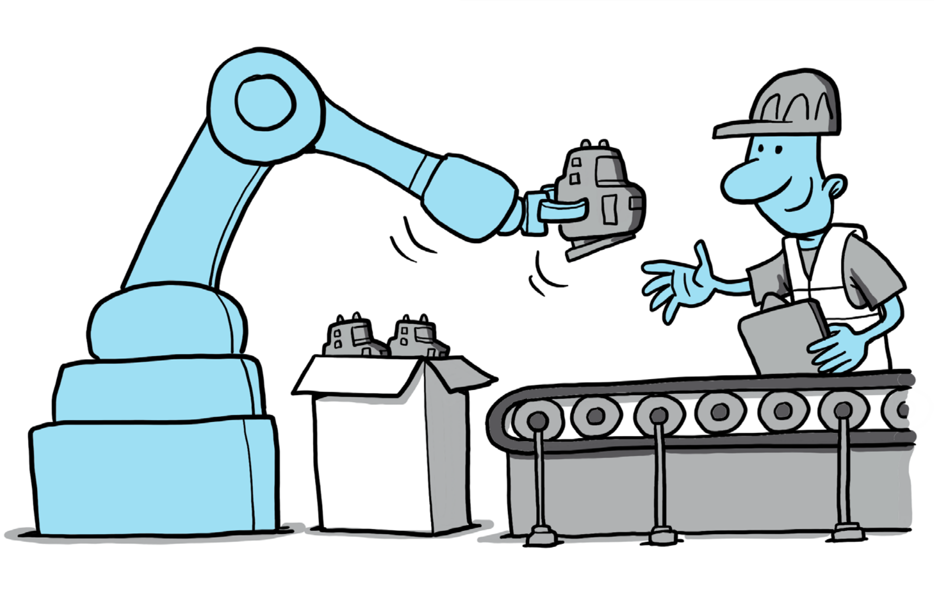
## 3.1 Description of the system

At one of their Slovenian factories, the company introduced a cobot whose primary purpose is to support workers in **lifting parts between workstations**. They use a **six-axis, one arm, medium-sized**, collaborative robotic system with a maximum payload of 15 kilograms, from a **third-party supplier**. The cobot utilises sensors in its base to ensure precision and high efficiency. It specialises in handling, machine loading, testing and logistics, working with or alongside people. The **cobot in this case study handles parts weighing between 2.5 and 3.5 kilograms** at an estimated pace of 600-700 lifts per day. These parts were previously handled by workers as part of the production and quality control process. The company identified that automating the **subtask of lifting** can provide **ergonomic benefits** for the workers at that workstation that would be beneficial in terms of OSH and important in the context of the demographic changes in the workforce.

The cobot **lifts** a product part from a production line and moves it to a storage pallet. This process is interjected by a worker, who performs **quality control** on the presented part. During this quality control, the cobot holds the workpiece in place, letting the worker perform their tasks without having to handle the weight themselves. This way workers can focus on the inspection without having to reposition the workpiece repeatedly by hand. Only if the product meets the standards is the cobot then directed by the worker to place it on the storage pallet and arrange it to be correctly positioned for further processing. At the production line in which the cobot currently operates, it covers around 80% of the production on its default programming created by the company. When there is a switch to a different project on the line, technical engineers must adjust the cobots' routines to support the new production. The cobot currently functions along hard-coded movement patterns without integrated artificial intelligence.

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.

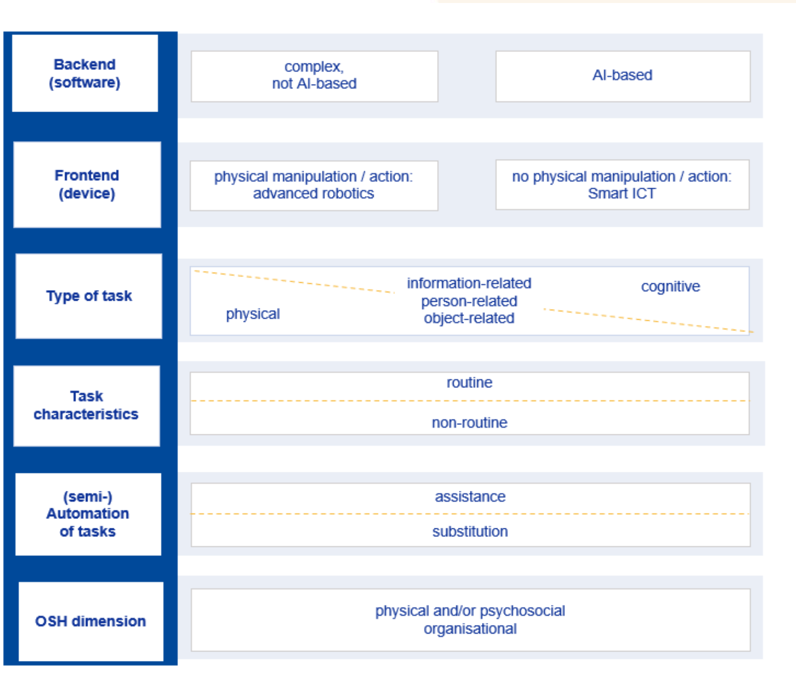
**Figure 1. Collaborative robot lifting parts in an automotive and industrial supplier**



## 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**




[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

According to this taxonomy, the one-armed cobot in this case study performs strength focused **manual tasks** with a **non-AI backend software**. It performs an **object-related**, **repetitive** task with **physical** manipulation of the workpiece. This **fully automates** the task of lifting the workpiece from an initial production position to a quality control station and then into a semi-permanent storage solution waiting for further processing or to the shipment. For the task of lifting the workpiece, human labour is **substituted** and the worker's focus shifts towards the cognitive task of quality control, which the worker performs independently. The latter described OSH dimensions affected by the robotic system are primarily **physical**, however the company also describes some **organisational** effects initiated by introducing the system into the workplace. These effects are not directly related to the task the robot performs, but rather due to the changes in production it incites. However, these effects are largely predicted to develop in the future and are detailed in a later section.

The **employees impacted** most by the introduction of this robotic system are **shop**floor workers. The job tasks of other employees, like the production engineer, health and safety engineer, or automation engineer, are affected, but their overall work activities are not. Researching technology-specific regulations or performing risk assessments were tasks performed by the engineers, but they are now performed by the robotic system.

**The general work activities** like scheduling, production process, hiring and task performance did not change due to the robotic system, as the automation is limited to a specific task in a larger production cycle. The primary users did see a change in both **their job content and routine**. They faced an increase in training to use the robotic system, as well as additional health and safety training. As a specific lifting task is automated, the workers' tasks shifted towards performing more optical checks on the workpiece than before. The full automation of lifting the workpiece has also resulted in the worker having more time during their **routine** to perform quality control tasks.

# 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 express a number of objectives and goals for the introduction of the cobot. They can be categorised into three major groups: **educational** goals, **commercial** goals and **OSH** goals.

As this was the first collaborative robotic system incorporated into the production line, a primary goal 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 learning about relevant regulations and current national and European laws regarding collaborative robotic systems. The production manager summarised the company's efforts as: '*The goal was to learn*.' This objective has been part of the company's approach to introduce new technology already before the implementation of their current cobot. There had been a prior project where a cobot was considered, however after an initial analysis of the case study, they concluded that the workplace would not benefit from a collaborative system.

The second group of objectives is more **commercially** oriented. This includes cobots as a means for innovation as well as a way to increase production.

The third group of objectives falls under the scope of **OSH**. Overall, this goal can be summarised as the intent to improve the workplace environment. Repetitive tasks are physically straining and tedious. Introducing the cobot was supposed to free the operators from heavy lifting and reduce repetitive movement. The cobot was installed to assist workers, as well as to reduce short-term and long-term risks and injuries. Facing an aging workforce, improving the ergonomics of workplaces is one way to allow workers to stay in their job longer, as well as a preventative measure for young workers to not suffer strain injuries in the long run. One long-term goal suggested by interviewees was to completely automate the physical aspects of production, and have workers perform only quality control tasks on the workpiece. Another goal was to free up the workers from the production line. This way they could either perform other tasks or be available to aid at other worksites.

The set goals can later be used to measure how successful the implementation of a robotic system was and therefore influence the future direction a company takes with the technology. The interviewees report that, overall, the **goals**, especially regarding the educational and OSH facet, have been **reached**. Workers are overall freer, and their physical workload has been reduced. In addition to that, the knowledge regarding a variety of factors, like the legal landscape and scope of application for collaborative robotic systems, has increased in the experts. It is too soon to tell if long-term goals, like the reduction of strain injuries, have been reached yet.

## 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 differs 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 an implementation, as the ones more broadly shared among several case studies.

In the beginning of this process, there was a **decision phase** where a robotic system was considered for implementation. The decision that a collaborative robotic system would be introduced at the work site in this case study was made by the company's management team in cooperation with the technology department. The department specialising in automation was then given the task of selecting the most suitable cobot for the task. Different models were considered before selecting a **preconfigured cobot** from a third-party supplier, which could then be programmed to perform the specific task. An decisive incident towards deciding for the introduction of the cobot in this specific plant, was a visit to another plant of the company, which had already introduced the same cobot. Learning from their implementation processes and success with the system overall contributed towards this plant deciding to install the cobot as well.

While deciding to automate the lifting task, the company took the **ergonomic impact** of the cobot at the workstation into consideration. These considerations are paralleled in the previously mentioned goals of **reducing repetitive movement and dull work**. One requirement for the system was to generally increase ergonomic working conditions and select a system designed to reduce physical workload for the operator. While the company did not design the cobot itself, its dimensions and how they change the workers space were considered. To handle the physical load, the cobot had to be quite large, however after installing it in the workstation, the operator had more room to move than previously.

### *4.2.1 Implementation steps*

After selecting a suitable cobot, the company took the next steps to install it on site. The first **testing phase** was initialised. This included a **risk assessment** and extensive **safety testing**, to gauge possible risks from the expended forces of the cobot, should it collide with a worker. After the safety-related **certification** and approvals were set, taking into consideration safety regulations and requirements, **workers were included** to get to know the system before using it in everyday operations. Before starting production with the cobot, there was an **education period** for the operators as well as for everyone in the factory. This education phase not only provided operators with the needed skills to use the cobot, it also reduced workers' reservations and safety concerns. After this phase, workers should know that the cobot is safe to use as well as how to use it safely. Operators receive separate training, which includes safety instructions as well as safety measures in case of an emergency. Once the cobot was fully operational, using it was **mandatory** for the operators.

### 4.2.2 Standards and regulations

To ensure proper workplace safety, the company adhered to a number of regulations and standards, both national and EU-based. Regulations specific for Slovenia were **The Health and Safety at Work Act**, **Rules of Health and Safety Requirements for Work Equipment**, and **Rules on Machinery Safety**. In addition, they used applied **ISO/TS 15066** and robot-related ISO standards, like the **ISO 10218-2** and **ISO 10218-1** on **safety requirements for industrial robots**.

### 4.2.3 Difficulties and challenges during the implementation

As part of the implementation process, the company faced several difficulties and challenges to overcome before fully integrating the cobot into their production line.

**Safety regulations** and **requirements** were major issues. The overall quantity made it difficult to select and determine relevant information. Regulations were perceived to be too complicated. The workers' safety was at all times a priority for the company, so they wished to comply with all necessary safety standards. Nevertheless, aligning present safety regulations with the existing production line posed a challenge to the technical engineers. The cobot needed to be slowed down from its maximum capacity to comply with the regulations, as otherwise speed and force checks exceeded the limits set by the current regulations. This was a trade-off between efficiency and OSH. As the cobot handles sharp and heavy parts, its movement paths needed to be designed to keep out of the workers' way.

A specific challenge rose from the **relative range of motion** of the robotic system regarding **height-specific regulations**. There are different forces allowed for robots working above the waist or above the shoulders. The cobot picks up a part at 100 cm height. Depending on the height of the operator, different forces would be permissible according to the regulations. Smaller workers are theoretically more at risk. Slowing the system down allowed it to be as safe as possible for all workers. At the same time, the system could not fall under a certain speed as it needed to keep up production to reach one of the primary goals.

In addition, the standards and regulations in Slovenia are described as outdated by the interviewees. The technology has since expanded in its capabilities and operational safety, so adhering to the regulations is described as not necessarily increasing safety but reducing efficiency.

In the initial research phase, the technical department also noticed that there is a **lack of good practice** examples for cobots. Those that were accessible were often based on companies based in Asia. As these companies do not have to follow the same rules and standards as countries in the EU, their transferability was limited. They found that compared to most Asian countries, setting up a cobot in the EU is much more difficult as there is much more documentation needed and regulations to consider.

Within the workforce there was also initial concern regarding the safety of the system. As they previously did not have any experience with cobots, some workers reported being afraid of the system. This coincided with a language barrier, as many operators spoke neither Slovak nor English as a native language. These specific challenges were overcome with specialised training, detailed in a later chapter.

The company also faced organisational issues regarding the implementation **time frame**. It was perceived as a challenge to complete all steps of the implementation process, **technology selection, risk assessment, testing phase, operator training and so on, within the given time frame** while keeping the production going. Including a cobot in production was found to be more time intensive than a fully automated robotic cell, especially due to the **extensive safety standards and testing**. Every month that a cobot is not functionally implemented, the return on investment diminishes. On the other hand, safety and training of the workers must not be compromised. The interviewees report that this has previously led to the conclusion that the workstation does not need a **cobot** but rather a fully fenced robotic cell.

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

The company involved its workers actively in the implementation process, with measures like early exposure to the cobot, training and education beyond the primary user. Worker participation in the implementation is a critical success factor for the successful implementation of manufacturing initiatives.[2] Facilitating conditions, like early and comprehensive involvement of workers in the introduction process of a new technology in the workplace, has repeatedly been found to have significant positive associations with technology use[3] and work engagement.[4] Communicating changes to workers has also been found to promote change-supportive behaviour among workers.[5] Additionally, training and education have repeatedly been shown to contribute to the success of technology implementation.[6,7] **As previously mentioned in the description of the implementation process, the workers were involved in the testing phase of the cobot, after safety certification and approvals were set up.**

Worker involvement in the process also includes receiving **feedback**. While the company did not perform interviews for formal feedback, repeated informal feedback conversations between workers, supervisors and technical engineers have taken place. This feedback revealed an important development over time. After the system was implemented, the workers did not report high levels of acceptance towards it. This was largely related to **fear of job loss**. While it was communicated that workers would not be replaced by the robot but rather go into higher positions or perform different tasks, this did not completely negate the initial fear of replacement. Additionally, prior to using the robotic system, there were concerns about the **physical safety** of interacting with a cobot. **These concerns were addressed during the worker training, however the interviewees reported that the most positive influence on all voiced concerns was actively using and interacting with the cobot.** This way, workers experienced the benefits of the system first-hand and could apply the knowledge gained during training. All interviewees reported that recent operator feedback has been positive. They find the cobot helpful and they notice the physical benefits from no longer moving and lifting heavy parts. Currently, they report no fear of the system, as well as no physical or mental performance pressure.

### 4.3.1 Training and worker qualifications

Worker training and education is a major element for the success of technology implementation.[5,6] The company started worker training as soon as all necessary safety certifications were in place. Next to learning how to operate the cobot overall, knowing how to operate the system safely was a primary focus of the training. Hence, all operators were trained in handling **emergencies and unexpected situations**. The training courses have received positive feedback from the workers' side. Beyond the training they already had received, they expressed the desire to learn how to handle errors on the machine themselves, so a special training course was implemented for them to acquire that skill. Operators who received this special training gained certification to also perform check-ups on the cobot.

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**. The automated task in this case study is a lifting task that does not require a deeply specialised or trained skill that would be lost if workers do not perform the task for a certain amount of time. Instead, this specific case study shows examples of both **reskilling** their workers, as well as **upskilling**. The provided training to operate the cobot is an example of reskilling a worker who stays in the same position as before the automation. They acquire new skills and knowledge to complete their job. Learning to operate a collaborative robotic system expands their skill set. In addition, **upskilling** their workers

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[2] Boyer, K. K. (1996). An assessment of managerial commitment to lean production. *International Journal of Operations & Production Management, 16*(9), 48-59. https://doi.org/10.1108/01443579610125589

[3] Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*(3), 425-478. https://doi.org/10.2307/30036540

[4] Molino, M., Cortese, C. G., & Ghislieri, C. (2020). The promotion of technology acceptance and work engagement in Industry 4.0: From personal resources to information and training. *International Journal of Environmental Research and Public Health, 17*(7), Article 2438. https://doi.org/10.3390/ijerph17072438

[5] Jones, R. A., Jimmieson, N. L., & Griffiths, A. (2005). The impact of organizational culture and reshaping capabilities on change implementation success: The mediating role of readiness for change. *Journal of Management Studies, 42*(2), 361-386. https://doi.org/10.1111/j.1467-6486.2005.00500.x

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

[7] 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

was one of the goals for the automation. Workers were supposed to be freed from repetitive, monotonous tasks, and instead perform more high-value tasks. These could be aiding other workers or, after having received the aforementioned training, perform basic error handling on the cobot itself. Furthermore, the company **upskills** workers through specialised training for them to acquire new qualifications. Some operators went from a standard worker to a specially certified Production Line Adjuster, who can perform check-ups on the cobot and solve malfunctions.

### 4.3.2 Feedback system and report handling

As previously mentioned, giving and receiving feedback was **vital** for the implementation process in this case study. This includes feedback on how the system is perceived by workers, as well as how the system performs. Many companies have specific structures to handle feedback and reports, to ensure quick and efficient communication. The company, too, has feedback systems in place and a specialised system to **report system-related near misses and accidents**. This is done via an online platform that forwards the report to the supervisor. They then contact the OSH engineer, or other involved parties, to identify and address any root causes or need for further action. The interviewees shared that, so far, there have not been any incidences with the cobot. This is attributed to the cobot's programming, as it does not move into any path the worker is in. In addition, the extensive safety training helps prevent incidences.

Feedback about the system as well as **worker concerns** are handled via informal channels and an **ongoing dialogue** between operators and supervisors. Both concerns (regarding physical safety and job security) and wishes (additional training) are communicated in this way and have led to organisational changes in the form of training courses and education.

### 4.3.3 Level of trust and control

The **level of trust** placed in a robotic system is regarded as dependent on a number of work-related factors. An adequate level of human trust towards the interacting system promotes appropriate system use,[8,9] **while extreme forms of trust can lead to adverse effects. Excessive trust can lead to automation complacency,**[10] **whereas insufficient trust may lead to neglect of the technology.**

The operators know how the robot functions and stops, and they report being confident in using it. There are no reports of distrust towards the cobot so far. The interviewees note that trust can be gained through experience. From the management's side, there is trust placed in the operators to know how to use the cobot so that they can work independently alongside it.

In addition to trusting the system, the **level of control** that workers have can significantly influence a number of factors. Especially in areas like physical manufacturing tasks like this case study, where the level of job control is naturally lower due to standardisation and quality control efforts, timing and method control are influential factors on workers' mental health, motivation and satisfaction.[11] The cobot used in the manufacturing line-up is hard coded, so operators **cannot individually adjust** the system. As the cobot is currently set up to not intercept any paths workers take, changing its movement would pose a potential risk. For safety reasons, any changes to the program code is done only by **experts**. However, workers can adjust adjacent workspace attributes, beside the cobot itself, like the height of their work desk. While the cobot performs its task in a production line, it has actually given the operator more time to perform the quality control tasks.

### 4.3.4 Company culture and structure

Introducing more robotic systems in a production process can impact social structures within a company. Scenarios in which workers previously worked in teams on a task and now work individually with a cobot are described when talking about automation contributing to phenomena like social isolation. However, the actual

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

[9] 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

[10] 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

[11] Rosen, P. H., & Wischniewski, S. (2019). Scoping review on job control and occupational health in the manufacturing context. *The International Journal of Advanced Manufacturing Technology, 102*, 2285-2296. https://doi.org/10.1007/s00170-018-03271-z

impact of a cobot on company culture and structure is highly dependent on the individual case study. Nevertheless, companies may consider providing additional support for workers who interact with the system, for example, counselling, psychological support or work organisation practices, to counter any adverse changes.

For their cobot, the interviewees do not see the worker at risk for these kinds of effects. The workers' social interaction and workplace social structure remained **unchanged** by the cobot. Potentially, the cobot has increased social interaction, as one interviewee mentioned that part of the new tasks workers perform might include aiding other workers. Overall, there have been no official or unofficial remarks on social problems in relation to the cobot. However, it was pointed out that if needed, the workers could ask their supervisors for support.

An important factor to consider is that currently, the company uses only one cobot. The interviewees pointed out that the impact on company and social structure has to be seen relative to this fact. They concluded that while, right now, the cobot has not had an impact in these areas, should more, or possibly all workplaces be partially or fully automated, it will change them considerably.

## 4.4 Future developments

Based on the insight gained from this case study, as well as previously mentioned earlier projects, the company is also considering its future steps regarding collaborative robotic systems. The interviewees report that there are concrete plans to introduce another cobot in a different location, and possibly also introduce more robots to automate the same task at this current worksite. In addition, there are two ongoing projects assessing scenarios for robotic application. However, fully automated robotic cells are the primary focus of future projects. This is due to those currently being easier and cheaper to implement.

**Overall, the cobot is seen as a good first step towards the formulated goals, but to assess the impact on OSH on a larger scale, more cobots would need to be integrated into the workplace**.

While the remaining task, the quality control of the workpiece, is still performed by a worker, the interviewees noted that AI could possibly automate this task in the future. However, they also highlighted that whether or not an AI will be used for this in the future strongly depends on the costs and complexity of the work tasks.

# 5 OSH impact

The introduction of advanced robotics or AI-based systems can have a wide impact on OSH. It can pose a number of challenges as well as opportunities unique to each case study. Therefore, 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 cobots allow highly individualised solutions for a company, they might also represent challenges specific to each case study. 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 as well as in operation.

### *5.1.1 Qualification and cognitive overload*

Workers' qualifications pose an OSH challenge when it comes to robotic systems in several ways. Generally, workers need to acquire new skills when starting to work with a cobot. Hence, the level of education needed for working in the same position rises. Acquiring this skill or applying it after training can pose a challenge for workers. So, while reducing physical workload, introducing the cobot might have increased a workers' mental workload. Additionally, not every worker is suited for or desires to be moved into a more supervisory position.

### *5.1.2 Fear of job loss*

Fear of job loss among the workers was present and openly communicated after announcing the introduction of the cobot. This fear was reportedly higher in older workers. While the company communicated that the effect of the cobot would be a reduction of physical workload, higher qualifications, more responsibility and possibly a higher paygrade, workers still expressed this fear. The interviewees noted that the cobot has, so far, not resulted in any job loss.

### *5.1.3 Job structure*

Helping the worker in their physical tasks was the primary goal of implementing the cobot. However, the interviewees noted that this may have resulted in changes to the overall job structure with unforeseen effects. Instead of working on a workpiece from start to finish, the worker is doing more side tasks. In the end, the overall workload may have increased instead of decreased, as there is more switching between tasks occupying the cognitive resources of the worker.

### *5.1.4 Physical risks*

Introducing a machine with direct interaction in a workplace always poses a physical risk to the worker. If not implemented correctly and according to the standards, or if mishandled, injuries can occur. While extensive risk assessment and safety training are effective measures to reduce risk to a minimum, some risk still remains in the form of unforeseen malfunctions or collisions due to workers not adhering to the safety distances.

### *5.1.5 Workers groups*

Specific groups can face unique OSH challenges. While demographic factors, like age and gender, do not appear to affect the **level of overall risk**, the interviewees noted that **height** might 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 workers can sometimes be difficult as, in 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 operate the cobot and, in some cases, do not understand the technology. So, while older workers do not form a risk group specific to this case study, workers with an aversion towards working with a cobot, as well as a limited understanding of it, pose a higher risk in general. It must be noted that this must not automatically be linked to age.

## 5.2 Opportunities

The introduction of cobots to the production site also held numerous OSH benefits and opportunities. Much like the challenges, these can be shared among other examples of robotic automation, as well as specific to this case study. The interviewees noted that if the company was to increase usage of advanced robotics and possibly employ AI-based systems in the production line, there could be many future benefits, beyond the currently known ones.

### *5.2.1 Worker qualifications*

The introduction of the cobot can also be an opportunity regarding worker qualifications and OSH. The interviewees repeatedly stated that the cobot allows workers to **expand their technological knowledge** and skill set. This includes not only how to control the robot but also how to handle errors. They also know the basic requirements and safety protocols of the cobot. The introduction of new technology to the workplace was described as an **endless opportunity to learn**, especially for older workers who previously had less interaction with technology. While this might lead to an initial period of **increased mental load** during the learning period, this is expected to normalise over time. Hence, the cobot has led to workers with higher qualifications and a wider skill set.

### *5.2.2 Physical workload and health*

The most prominent OSH benefit is the decrease in physical workload and the resulting health benefits. The reduction of repetitive, physically taxing moves is expected to reduce strain injury in the long run, specifically **strain on the shoulders, arms, fingers** and **back**, as well as prevent accidents and injuries during everyday work. This and an overall improvement of workplace ergonomics is also intended to allow older workers to stay on the job longer and younger workers to grow older healthier. The company is already experiencing a shift in worker demographics with an increase in older workers, hence this is one of several steps addressing this change.

Additionally, a cobot allows people with health restrictions to work at that specific workstation, as being capable of repeatedly lifting workpieces is no longer a requirement.

### 5.2.3 Task variety

Automating repetitive and monotonous tasks also holds the potential for workers to have greater task variety in their job. By not having to spend their attention focused on safely and efficiently lifting and setting down the workpiece, they can instead focus on other tasks at the workstation. The interviewees have stated that they want their workers to perform more **intelligent, high-value tasks**, and reducing monotony is part of that. The opportunity for greater task variety also goes hand in hand with the process of upskilling workers, described above.

### 5.2.4 Wellbeing

An overall more ergonomic workplace can have positive effects on workers' wellbeing. The cobot specifically has reduced physical workload, but an added OSH benefit the interviewees listed is that workers are now freer in several ways. As the cobot is set up to meet the highest safety standards, workers are **not required to wear any additional protection gear**, while simultaneously working in a safer work environment. Furthermore, as the task previously was, and presently is, part of a production line, performing the lifting, inspection and storing tasks was, to a certain degree, bound to a work cycle time. The cobot now performs two of these tasks, freeing up the workers time, allowing them to perform the remaining tasks under **fewer time constraints**. There is evidence that with increased cycle time, the wellbeing of workers improves.[12] One interviewee reported that, as a result, the workers experience **less stress** than before.

## 5.3 Barriers and drivers

Many companies go through the process of integrating advanced robotics or AI-based systems into their workspace 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.

### 5.3.1 Barriers

While robotic systems themselves are not an entirely novel technology, in recent years, a plethora of new and interactive robotic systems have been created, which are unlike previous industrial robots. There is **a limited number of available case studies**, most of which are based in **Asia or the United States** and have limited transferability due to the drastic differences in legislation and regulation. In addition, general **experience with problems** and errors, specific to the cobot, is low. This is not only in the company itself but in general. The company found it **highly beneficial** to visit another company's worksite that was already using the same robotic system. But having this kind of match accessible is rare for a lot of cobots, limiting companies' ability to learn from others' experiences.

Another barrier the company encountered was the **unexpected extent of safety requirements and documentation**. This parallels the previous barrier of general lack of experience in the area. Introducing a cobot to a workspace came with a higher demand for documentation, more complex safety regulations, and concepts to consider and implement. The paperwork needed to document everything appropriately, which significantly slowed down the process. Additionally, the current legislation and standards for robotic systems are considered by the interviewees to not be reflective of today's technology and its capabilities. **Matching this legislation with today's technology, without creating an inefficient system, proved to be a time-**

[12] Backhaus, N., Rosen, P.H., & Wischniewski, S. (2019). Tätigkeitsspielraum und Gesundheit bei Beschäftigten mit Taktarbeit in der industriellen Produktion. In Proceedings of *65. Kongress der Gesellschaft für Arbeitswissenschaften*. GfA-Press. https://gfa2019.gesellschaft-fuer-arbeitswissenschaft.de/inhalt/A.9.14.pdf

**consuming process.** One of the interviewees summed this up as: '**Newer technology demands newer standards.**'

**Change aversion** proved to be a barrier during and after the implementation process. While some workers more readily embraced the benefits the cobot offered them, others were less cooperative. This proved to be especially difficult, as the use of the cobot is mandatory. **Fear of being replaced** by the system as well as a **low understanding** of technology were identified as contributors to the aversion. Additional education was offered to operators to reduce resistance in the workforce, however singular incidences where the cobot was not supervised correctly still happened in the initial phase. 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 as early as possible and address them accordingly. The interviewees note that time has reduced resistance, as workers grow more accustomed to the system.

Lastly, **matching the new technology to the existing production line** was a challenging task for the production planners. Some parts of the production line were conceptualised in the 1970s, hence it was difficult to make the cobot compatible with them while adhering to all necessary safety regulations. While cobots are a flexible tool, integrating them into a pre-existing production line might limit this flexibility considerably. Technical complications of the cobot proved hard to be foreseen. This relates to a lack of experience with the technology as, for example, the cobot would sometimes stop working for no apparent reason. As a result, the process was adjusted to ensure that if the cobot stops, production can continue seamlessly. However, the technical engineers have since gained experience with the system and can avoid or explain most malfunctions.

### 5.3.2 Drivers

The company identified two major drivers throughout the process.

The first one was that **workers with a high affinity for technology** fully supported the introduction. These workers saw the benefit the system offered them and embraced working with it, as they were provided with additional training and resulted in becoming **upskilled workers**. As mentioned above, worker participation is a major contributor to the implementation of technology in the workplace. Having highly motivated workers not only during the design and installation phases but also in ongoing production was perceived as a driving factor to the success of the implementation.

The second driver was the expertise received from the external company and the benefit gained from their experience and knowledge. Visiting the worksite as well as meeting with their **safety engineers** helped the company understand the scope and possible hurdles of the upcoming process. The exchange was perceived as beneficial for both sides.

## 5.4 OSH management

New technology can lead to a change in work procedure. This includes expectations for the technology and subsequent OSH management.

### 5.4.1 Expectations for OSH

When it was announced that the company would introduce a cobot, the expectations regarding OSH were largely focused on the physical benefits the system would have for workers. The goals of the company to introduce the cobot already had a focus on OSH, hence the related expectations. When the interviewees were asked if there were specific OSH expectations for their field of work, none besides those previously mentioned were named. Their expectations towards the cobot have not changed over time, however after having implemented the system, the expectations have been met.

### 5.4.2 Emerging OSH risks and monitoring

New technology has the potential to create new OSH risks. When it comes to the cobot the company has installed, there were a number of previously known OSH risks, like physical risks resulting from misuse, and fear of job loss among workers. However, any physical risk can be minimised by using the system as intended and according to protocol, according to both the management's perspective as well as that of the safety engineers.

From the automation engineers' perspective, an unforeseen consequence was that the robotic system was implemented to support the worker but ultimately had them perform more **disjointed tasks**, possibly increasing their overall workload.

**Continuous monitoring** of OSH-related developments in the company is one way to identify new or emerging risks. In the case of the cobot, **risk assessment** in the workplace is performed on a regular basis in addition to preventive maintenance. Error messages are logged to help identify problems should they arise.

On the workers' side, they have **access to a doctor**, should they have any upcoming health concerns, and frequent meetings for safety training for all workers, where concerns or observations can be brought to a supervisor's attention.

### 5.4.3 Communication strategies

Regarding any OSH risks and opportunities that were identified, these were **communicated** to the primary users via the education programmes and training programmes they received before operating the cobot. Workers not primarily using the cobot also had the opportunity to receive information on the cobot and its benefits.

Any changes or **modifications** to the cobot are communicated immediately after implementation. However, this only applies to minor changes. Operators are not informed about software changes as they don't affect them. In case the robots' tasks change and functionality is affected, operators would be informed at least one shift in advance.

### 5.4.4 Organisational and social impact

Some robotic systems might incite a change in the organisational or social structure of the work environment. Installing cobots in places where workers were previously working together, for example, could lead to social isolation. In this case study, however, the cobot did not as yet have any impact on these structures. The workstation was operated by a single worker even before the cobot's installation. As operators are now freer at their workstation and potentially have time to aid other workers, social interaction might have even increased. However, there were no data collected on this matter to quantify the pre- and post-state.

Another reason why both the organisational and social impact of the cobot has been limited is rooted in the fact that there is currently only one cobot in operation. Especially from the management's perspective, should all workstations be fitted with either a cobot or a fully automated robotic cell, there would be the need for organisational adaption.

### 5.4.5 Integration of OSH management

To manage OSH risks arising from the application of the technology, the company has ensured that the cobot adheres to all necessary legislation and safety regulations. All machines have a CE mark and proper documentation. Furthermore, simulations and additional checks are run to identify any risks.

The cobot has sparked changes in OSH management within the company. As it was a new technology, learning about the safety requirements and legislation related to it increased the scope of factors OSH management had to cover. To make sure the system was safe, **risk assessment** and special **inspections** for the cobot were performed. These measures, however, will be reduced to only the necessary procedures, now that one implementation has been successful.

Furthermore, specialised **OSH education and training** for the robotic system had to be created. This can be used as a basis for any future robotic systems.

### 5.4.6 Need for action

There were a number of different stakeholders and actors involved during the implementation process of the cobot. These were internal (for example, management, technology experts, workers council) or external influences, such as other companies and legislation. The interviewees did not identify any specific need for action from any company's internal actor. When it comes to external factors, several points were raised. They see pressing need for action on the side of **legislation**. Especially from a safety engineer's perspective, legislation does not include robotics in their current form and is **not specific enough** in the application. From an automation engineer's perspective, similar criticism applies to the standards, which currently do not reflect newer technology from their point of view.

Additionally, there is a need for more **European-based good practices**, **cases studies** and **shared expertise**.

### *5.4.7 Cybersecurity*

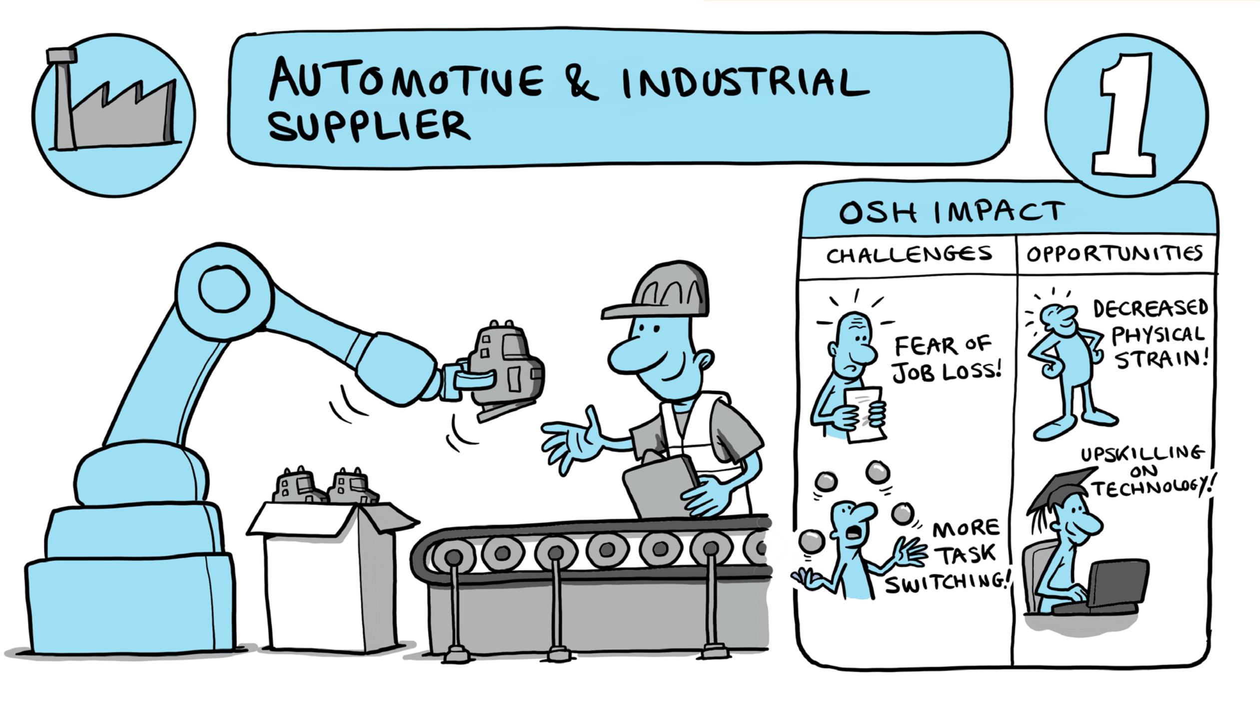
With technology becoming increasingly interconnected and data being a resource needed by some AI-based systems to improve their functionality, the topic of cybersecurity becomes prevalent in companies employing these technologies. The way that cybersecurity is handled at a company level is a key factor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

However, this case study did not take any additional measures towards cybersecurity. The robot is not connected to the internet or connecting servers and is therefore **not considered a target**. While malware introduced via a direct connection (like a USB) could potentially give someone control over the robotic system, the high-risk low-reward situation of the attacker makes the robot an unlikely target. The company concluded that even if someone would be able to externally control the system, it **does not pose any OSH risk**. The robot moves within set boundaries regarding its speed and strength and is unlikely to injure someone. As it is also not connected to the company's servers, it cannot be used as an access point to those either. Hence, no additional cybersecurity measures needed to be taken.

Within the context of cybersecurity, data privacy is also a concern. Some AI-based systems either handle or collect person-related data, which creates the need for additional worker protection. However, the company's **cobot does not collect** or handle any **person-related data**. While workers can adjust parameters of the cobot to their individual needs, like desk height, this information is not stored. Hence, the company currently does not report any particular concerns or measures taken regarding the cobot.

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

**Figure 3. Collaborative robot lifting parts, posing challenges and opportunities for OSH**



# 6 Key takeaways

There are a number of key takeaways from this case study and the experience related to introducing a cobot into their production line.

Understanding that OSH and related factors have to be considered on a **long-term** spectrum next to immediate health, safety and ergonomic benefits is highly important. The use of cobots in the workplace reduces the amount of repetitive movements and lifting workers need to perform and can help prevent strain injuries. As a result, older workers are able to stay at their job longer, and younger workers avoid 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 used to address it.

Another factor impacted by the passage of time is the **acceptance** of the system by the workforce. This case study indicates that some workers have a lower initial acceptance for this kind of technology, based on factors such as fear of job loss or lack of skill. This case study shows, however, that after using the cobot over a period of time, acceptance increases. 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 or other companies, this could mean that workers are put into contact with the system as early as possible, to start this process. The present company has already involved its workers as early as the initial testing phases. Within standardised manufacturing, there is a limit to how early worker involvement is possible. This case study, however, highlights that early and direct involvement is most beneficial to shorten this acclimatisation period. This could involve additional early practical training courses prior to the cobots' installation, or other forms of primary exposure, like a demonstration device in the company.

The interviewees unanimously agreed on the benefit of **learning from good practices**, and 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 published 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 into their work environment, reaching out should be a step considered by those who have yet to go through the process.

The experts in this case study also reported a need for **updated legislation** to reflect robotic systems in their capabilities and safety requirements more accurately.

The company sees the OSH benefits a cobot has for the workplace, as well as the need to face and address the challenges it brings with it. Overall, the cobot is seen as a **successful step towards innovation** and an overall learning success. The main goals on both the economic and OSH side have been reached through the system. There are considerations to continue with robotic automation in different forms, including cobots and fully automated robotic cells.

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