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Enabling human-robot collaboration and intelligent automation in the automotive industry:

A study of stakeholder perspectives

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SUMMARY AND CONCLUSIONS

Introduction

Intelligent and flexible robots using sensors and adaptable programming are promoted as state-of-the-art technology with great potential of improving industrial production. It is commonly associated with concepts such as artificial intelligence, smart factory, agile manufacturing, and industry 4.0. Providing flexible solutions is said to facilitate the automation of complex tasks that are done manually today and enable humans and robots to work simultaneously with a task. It is argued that this will allow a flexible production that can cater to shorter product cycles and increased demand for customized products. Large manufacturers showcase such installations in their factories to demonstrate that they are keeping up to speed with technological development. While the technology is associated with promises to improve production, the benefits over classic high-speed and high-volume automation are yet to be proven.

Previous research into the functionality of various types of collaborative robotics is mainly concerned with evaluating the technology in experimental settings. Consequently, while various installations are evaluated in laboratories, little research is done to understand how such automation might work in complex organizations with an established production. Through in-depth interviews with stakeholders connected to the automotive industry, this report aims to fill such a gap and discuss under what circumstances such technologies can bring added value to industrial production.

Purpose and aim

With this background, the report investigates how expert stakeholders in Sweden understand potential benefits and pitfalls in introducing intelligent automation in final assembly in the automotive industry. The main focus is on collaborative robots, so-called cobots, and autonomous transport robots (referred to in this report as Autonomous Transport Robots or ATRs). Qualitative interviews explore stakeholders' views on introducing the new technologies in question. Stakeholders included in the study are i) professionals in different capacities within the industry, ii) researchers in engineering science, and iii) some key stakeholders from government organizations. In selecting industry stakeholders, the main focus is on one multinational company within the automotive industry (Volvo Group and Global Trucks Operation, GTO), and the researchers interviewed are from Chalmers University of Technology in Gothenburg. The data has been collected through 26 in-depth interviews conducted between January 2019 and May 2020.

The theoretical point of departure of the report springs from science and technology studies and organization theory. Being an explorative study, it covers a broad range of topics related to introducing intelligent automation in final assembly, including perceived benefits, perceived technical and organizational challenges, and stakeholders' views on related safety and regulatory issues. The study also explores these stakeholders' views on trends and future development of technology and automation and their views on the future of intelligent automation in industrial production. By including stakeholders from various parts of society, the study also explores differences and similarities in the views of the various stakeholders.

Perceived benefits and obstacles

The study concludes that the general view among stakeholders is that intelligent automation has potential advantages and uses that can make it worthwhile to invest in such technology upgrades in certain parts of the final assembly. Perceived benefits include improved ergonomics, increased product quality, and improved safety. Potential benefits are especially emphasized when it comes to automating transportation within the factory and the sub-flows in assembly. However, the stakeholders, especially from within the industry, recognize several obstacles in introducing intelligent automation in the factories. Available commercial products (e.g., robots, carts, sensors, and grippers) are generally not considered sufficiently developed for the need for speed, accuracy, and quality in production. Also, equipment such as cobots and ATRs are understood to be challenging to integrate with current technology in the factories, and the transition phase creates a catch 22 where it is difficult to reach the critical mass of automation where there is sufficient knowledge and experience of intelligent technologies in the organization. Furthermore, the stakeholders at Volvo GTO understand many of their components to be too heavy and not sufficiently well designed for (intelligent) automation.

In addition to technical obstacles, there are several perceived organizational obstacles to installing intelligent automation that relates to how to distribute roles and responsibilities between subsections and stakeholders within the organization, how to divide tasks between human operators and robots, how to train operators, and how to introduce intelligent automation in production in a way that establishes trust in the new technology. The organizational challenges are related to the fact that intelligent automation must be coordinated in the organization as changes are needed in the product's design, preparation, production, and aftermarket.

Furthermore, current regulations are generally considered an obstacle for efficiently introducing intelligent automation by requiring costly risk assessments and redundant safety systems that make the automation too expensive and too slow. The regulations that apply to intelligent automation are not considered to align with norms of acceptable risk, and many of the respondents, both within industry and academia, recognize a need to adapt or even radically change current regulations to facilitate intelligent automation.

Differences between stakeholders

When it comes to perceived benefits, there are very similar views both within the industry and academia. When it comes to obstacles to intelligent automation, the industry experts are more articulated than the academics. Although recognizing several benefits and potential areas of use, the middle management in Volvo GTO remains largely reluctant. They understand obstacles in terms of compatibility with existing production and infrastructure, the performance of available intelligent technology, and existing regulation and safety standards that hinder large-scale investment in such technologies. They simultaneously stress the importance of keeping up with technology development to understand when it is sufficiently developed to make investments beneficial. Researching and evaluating state-of-the-art technology is also a way of demonstrating that they keep up with technological development and create an attractive workplace for their employees. The interviewed stakeholders from the R&D department are more positive towards intelligent automation than the managers responsible for the production in the factories. The operators interviewed for this study are favorable to intelligent automation from the outlook that they believe it to make the Swedish factories better equipped for global competition, and a view that technological development improves safety and ergonomics. Thus, there are differences between stakeholders at various positions within the business company.

Experts from the university recognize some of the problems but are generally more favorable to these solutions from developing technology. Researchers within engineering studies naturally take an interest in developing state-of-the-art technology, including intelligent automation. They understand that it is in the nature of their scientific field to do whatever is possible to do. From their position, human-robot collaboration and intelligent automation create an exciting new avenue of potential studies with new results to publish, and smaller robots that are relatively easy to program are understood to be beneficial in teaching and creating adequate case studies for students learning automation. Moreover, they collaborate with the industry for good case studies and co-funding their research projects. Stakeholders from the government do not have an elaborate opinion on the technology in question but deal with these matters from the perspective of their organization and the legal framework guiding their work—and relates to the promotion and regulation of intelligent technology in the same way they would deal with any other technology.

Technology infusion

The study identifies and presents factors determining the infusion of intelligent technology from the empirical material in its entirety (see Figure 2 in the report). This includes external inducement mechanisms, internal inducement mechanisms, and blocking mechanisms (external and internal). The most crucial external inducement mechanism is technological development outside the organization and moves from competitors—meaning that investments made by competitors are an important motivation. This inducement mechanism is not a mechanical process; instead, the competitors' moves are evaluated and translated to the context of their production. Other external inducement mechanisms include available research funding, national and supranational research strategies, and information from media and robot manufacturers. The internal inducement mechanism includes belief in competitive advantages in production, discursive advantages (e.g., technology in production aligned with product branding), and responsiveness to external inducement mechanisms. The last category signifies that there must be some internal mechanisms to pick up and evaluate information from the outside world.

When it comes to blocking mechanisms, the most important is an understanding that the cost of the investments will not correspond to the benefits. Also, current regulations are perceived by nearly all stakeholders as obstacles to intelligent automation—especially if robots are operating in the same physical space as human operators. Other blocking mechanisms include incompatibility with technology and organization; i.e., existing factories, technologies, and organizational structure create a path dependency when it comes to technology upgrades. Furthermore, previous negative experiences of poorly designed workstations or the use of immature technologies function as a blocking mechanism for further development and investments.

Based on the study's findings and the authors' experience with collaborative applications, this report makes suggestions for a successful introduction of human-robot collaboration in the automotive industry.

- Changes in regulation and safety standards are required to facilitate intelligent automation. We identify a need to standardize and streamline the process of CE-labeling and risk assessment for intelligent automation systems. Furthermore, we recognize a need to develop the typology of modes of operations based on the need for flexibility and efficiency to enable safety measures relevant to intelligent automation.

- Further development of shared standards is required both to streamline safety evaluations and to increase compatibility between various devices that can be used for intelligent automation. While this is primarily an internal issue for industry stakeholders and standardization organizations, standardization is also an area for policy interventions, for example, by government or supranational intervention to change current standards or establish new ones on the EU level and beyond.

- Further technology development and increased technical competence are required. While this is primarily a concern for industry actors. States and supranational bodies can also help facilitate development through continuous research funding into developing state-of-the-art technology and applied technology to help promote competitive industries. Many of the interviewed stakeholders widely recognized a need for increased competence in automation. Government and government bodies can provide additional funding, and other forms of incentives to encourage technical universities and colleges to make education more relevant to the needs of the industry.

- This study has shown that cobots and ATRs are used in ways that emulate traditional automation, i.e., performing repetitive tasks using the control system of the individual robot. Novel types of intelligent control are necessary to increase intelligent technology's flexibility and general usability. Intelligent automation must be both flexible and efficient; it must be highly adaptive, cope with unforeseen events, handle variations of parts and resources, interact with both humans and other robots, and have a significant degree of freedom to perform complex operations. It must also focus on how humans and non-humans can maximize the performance taking its departure in the qualities and capacities of the humans and robots, respectively. Such flexibility can only be achieved using an AI-driven control system and advanced sensors.

Keywords: Human-robot collaboration; Intelligent automation; Artificial Intelligence; Smart factory, Industry 4.0

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1. INTRODUCTION

Artificial Intelligence (AI) and collaborative robots in automation have become much-discussed topics in media and scholarly literature. In an article search in Scopus, which encompasses all printed Swedish newspapers, we can see a rapid increase in the use of keywords such as *artificial intelligence, smart factory, agile automation, and collaborative robotics* (Larsson & Bengtsson 2022). In a report titled *Creative machines* from the company Ericsson (2019), it is argued that a new generation of automation powered by AI will alter the labor market and the way things are produced. Swedish Agency for Economic and Regional Growth published a report stressing the importance of supporting digitalization and the intelligent industry in Sweden to create competitive industries (Dnr: 2016/011). In line with this development, government and private research institutions spend much research funding on the development of intelligent technologies.

While described as a way of creating competitive industries, this type of innovative automation is not necessarily focused on increasing the capacity to produce large quantities of serial-produced products. A stipulated advantage is their capacity to make automation more flexible (Villani et al. 2018). It is argued that this is a necessary response to societal change, which entails demand for shorter product cycles, customized products, and possible rapid fluctuation in demand. Shorter product cycles will shorten the time frame to adjust the production in the factories to new products. In response to such a development, flexibility is understood to give a competitive advantage. This ideal for automation is commonly called *agile automation* (Sadik and Urban 2017), enabling increased resilience because the production is easier to adapt. Because the benefits of such solutions are measured differently, i.e., in terms of increased flexibility and adaptability, this technology can be understood as *paradigmatically* different (c.f., Kuhn 1996).

The established actors in the automotive industry do not only face competition from cheap production in low- or middle-income countries—there are also new competitors in the high prices segment. The car-manufacturer Tesla, for example, is a rapidly expanding company with one of the most elevated market valuations—offering only electricity-powered cars. Given the strong incitements from governments and customer demand, the major manufacturers within the automotive industry have also started producing electric and hybrid vehicles. In the transformation towards electrification, a newly established actor such as Tesla might have advantages over the traditional manufacturers because they do not have luggage of factories and technologies and significant investments in existing infrastructure and technology. So, while established manufacturers are starting to produce electric cars or hybrid cars, competitors such as Tesla and other companies solely focusing on electric vehicles have competitive advantages as they can build their factories to the needs of that product.

There are also many uncertainties regarding the future of the automotive industry. A politically motivated ban on fossil fuels would require a rapid restructuring of production for incumbents in the automotive industry. We can also see trends in society that favor increased product diversification, faster product cycles, and increased demand for customized products. All these trends create uncertainty about future products and product variability. They might require a capability to swiftly adjust the production to new products if manufacturers do not wish to become obsolete. Another recent event demonstrating the need to make swift changes in production is the covid-19 global pandemic. It exemplifies the need for the production industry to make adjustments in the production dependent on the availability of materials or parts from subcontractors.

As a response to these challenges, it has been suggested that the introduction of intelligent automation can make production more flexible and require fewer investments than large-scale specialized automation. Smart and creative machines, such as small robots and self-propelled carts that are easier to program, are argued to make production more flexible and resilient. In their marketing and communication, robot manufacturers stress that the advantages of such collaborative solutions are that they make it possible to automate complex assembly processes that are done manually today and make production more flexible by the possibility to "automate the assembly of many types of products on the same line" (ABB 2022a). Universal Robots, a manufacturer specializing in collaborative robots, writes in promoting their product, "Don't be limited by traditional robots that can only do one thing. Our robots are lightweight, space-saving, and easy to re-deploy to multiple applications without changing your production layout. Moving the robot to a new process is fast and easy, giving you the agility to automate even small batch runs and frequent line changeovers" (Universal Robots 2022). These advantages are also recognized in the research literature; for example, Villani et al. (2018, 248) write: "Being possible for the worker and the robot to work alongside each other in collaboration, the worker's productivity is enhanced, while their stress and fatigue are reduced. The greatest advantage of collaborative robots lies in the opportunity to combine the advantages of automation with the flexibility and cognitive and soft skills of human workers".

There are also other benefits to collaborative automation. It is said to help improve the work environment, relieving workers from performing ergonomically demanding tasks. Universal Robots advertise their collaborative robots on their homepage, saying: "Give dirty, dangerous, and dull jobs to robots to reduce repetitive strain and accidental injuries to humans" (Universal Robots 2022). Increased flexibility, safety, quality, and ergonomics is also how ABB markets their collaborative YuMi robot (ABB 2022b). It is argued that collaborative automation could make production more competitive by enabling automation of parts of the final assembly that is now mostly done through manual labor in the automotive industry (ABB 2022b). By automating parts of the final assembly in Europe, the hope is that they will be able to compete with manual production in low-income countries.

In semi-automated or hybrid production, operators collaborate with a human. [1]This can be done through different degrees of engagement between humans and robots. Robots sold as collaborative robots (Crowe 2022) can be programmed similarly to traditional industrial robots. Still, it is also possible to program these machines to become a part of an intelligent system with a joint control system including small robots, automated guided carts, other appliances, sensors, and humans. AI-driven control systems can be used to coordinate the actions of the individual units, and reinforced learning can be a part of such a program to improve the capacity of such systems continually.

Issues related to collaborative robots and other intelligent and self-learning machines concern industry stakeholders as a potential resource for improving production. However, it is also a concern for expert stakeholders in government authorities (regulation and research funding), universities (technological development), unions (work safety and work environment), as well as in other societal organizations (e.g., standardization). These actors are engaged in development, regulation, safety, and dealing with societal consequences of technological development. Introducing AI into automation systems that can collaborate with humans is also a concern for factory operators who will work with such machines. These societal actors have a mutual concern for the safe development of valuable tools yet may have different concerns and understandings depending on position and organizational affiliation. From previous research, societal stakeholders have different rationales for decision-making and problem assessment depending on their managerial role and responsibility and the values at stake (Apostolakis and Pickett 1998; Jenkin-Smith and Bassett 1994; Larsson et al. 2019). Therefore, different actors can be expected to have divergent views on the prospect of utilizing collaborative and intelligent automation.

The aim of this study is thus to investigate how stakeholders within the automotive industry, as well as various other stakeholders in the Swedish society, view the possibility of introducing artificial intelligence in the final assembly of the automotive industry. With their perspective as a background, the report will articulate ways forward for enabling such a development. The study will focus on new and innovative machines such as collaborative robots (cobots) and autonomous transport robots (ATRs) [2], as well as AI-driven control systems and automation of cognitive processes—technologies that can be understood as part of a fourth industrial paradigm (Industry 4.0). If an AI-driven control system is used, the machines in

1 Example of robots that are referred to as "collaborative" or cobots are Universal Robots, ABB (Yumi), KUKA (iiwa), Fanuc (CRX), Omron (TM), to mention a few.

2 ATR is used in this report to refer to transportation robots that are equipped with sensors and can replan their route depending on the environment, in the interviews such devices are referred to as AGC (automated guided carts).

question become autonomous or perceived by human operators as autonomous because of the control system's capacity to re-plan and adapt its execution sequence due to changes in the environment and operator input. Cobots and ATRs also have in common that they are small, easy to program, and designed to operate in the same workspace as humans.

Being an explorative study, it addresses how stakeholders understand the development of cobots, ATRs, AI-driven control system, and innovative automation, and what benefits they can see from their point of view, how they understand and define potential problems and obstacles for further development in the industry, and what changes (within the organization as well as in society) are understood as necessary for these technologies to be beneficial for production in final assembly. Volvo GTO and subcontractors and researchers collaborating with this large company are the main focus.

At stake in introducing intelligent automation are also broader societal issues. It is argued that increased automation will require new competency accompanied by a need to change education and training to equip employees with the skills needed for the labor market (Ericsson 2019). There is also a fear that this development will radically reduce the number of available jobs. Although historically, new jobs have been created in the wake of technology development and increased automation, some scholars show that an increased production today doesn't necessarily produce more job opportunities (e.g., Fölster 2018). If robots replace human workers, it is a concern for these individual workers and society. For example, a decreased reliance on human employees might reduce the state's revenues from taxation (Ericsson 2019). Intelligent automation and automation that can make decisions or re-plan their route pose essential questions regarding the need for future regulation or changes in current regulation (e.g., Arvidsson 2013; 2018; 2021). Consequently, several societal challenges are associated with a shift to utilizing AI in automation to a more considerable extent; further discussion about how these challenges should be dealt with in society is needed.

In pursuing the report's inquiry, some initial definitions will be of the essence. In talking about "intelligent automation" in the context of this report, we refer to collaborative automation solutions that coordinate the actions of robots, humans, and other machinery in an intelligent way. As such a machine, a robot cannot be intelligent or collaborative, but "collaboration" refers to an automation system consisting of many parts. Many automation solutions that include cobots and ATRs used today in industrial production are not intelligent but instead what we refer to as traditional automation. Traditional automation is not flexible—if something happens unexpectedly, the system may stop executing the current task or require a repair or a complete reset. To increase the system's degrees of freedom and to make a design truly intelligent and flexible, it must have an AI-driven control system that includes an online decision algorithm that can plan what task to execute to handle unforeseen events (which inevitably will be the case when an automation system includes human operators).

In this report, we are using the term *intelligent* automation to describe such automation systems, which incorporate the robots and humans on equal terms, are highly adaptive, can cope with unforeseen events, handle variations of parts and resources, interact with other humans and robots, and have a significant degree of freedom to perform complex operations. If such flexibility can be achieved while efficiently accomplishing various goals, it can be defined as an intelligent automation system. As presented in this report, the respondents interviewed often conflated traditional and intelligent automation, resulting in industry stakeholders failing to see the potential benefits of intelligent automation. Establishing such a definition will be an essential part of discussing how automation can bring advantages to the production in final assembly.

This report aims to explore existing views and perceptions of collaborative robots and intelligent automation and, with this as a point of departure, discuss what is necessary to make such technologies beneficial. It will provide a holistic view of obstacles to implementing intelligent automation in a complex organization. It is vital to articulate the problems as accurately as possible, so that suggested solutions correspond to these problems (Bacchi 2009). This research contributes to an interdisciplinary research discourse and a contemporary political debate on addressing the consequences of technological development. More specifically, the research report seeks to answer the following research questions:

RQ1: What benefits and challenges do stakeholders recognize in introducing intelligent automation in final assembly? [Answered in Chapter 5.2 and 5.3 and summarized in Chapter 6]

RQ2: What factors are understood to enable and hinder the infusion of intelligent technology in the final assembly in the automotive industry? [Answered in Chapter 5.2, 5.3, and 5.4 and summarized in Chapter 6]

RQ3: How do expert stakeholders from various sectors of society envision the future of production in final assembly, and how do these differences correspond to their societal role? [Answered in Chapter 5.9]

RQ4: How do the various stakeholders in their different capacities view current regulation, and to what extent do they recognize a need for new regulation? [Answered in Chapter 5.5]

RQ5: How is intelligent automation understood to change the nature of work and the distribution of roles and responsibilities of the workers in the final assembly of the automotive industry? [Answered in Chapter 5.6]

> **RQ6**: Based on the findings of the study, what is required for intelligent automation to create advantages in industrial production with a focus on the automotive industry? [Discussed in Chapter 7]

The study will seek to answer these questions through empirical data collected from in-depth interviews with stakeholders in different areas of Swedish society. The expert stakeholders included in this study have extensive experience and in-depth knowledge about these topics that can provide valuable knowledge for the inquiry of this report. The primary point of departure is that technology upgrade is situated in organizational structures, organizational culture, and external institutions (such as regulatory bodies and bodies supporting innovation and standardization).

The report proceeds as follows. *Chapter 2* presents previous research on intelligent automation and technology. *Chapter 3* presents the theoretical perspective and assumptions of the report. *Chapter 4* describes how the study was carried out, the method used for selecting respondents, the development of research items, and how the interpretation and analysis of empirical data have been carried out. *Chapter 5* presents the results and analysis of the data. This chapter is divided into nine sub-sections: i) provides an overview of the involved stakeholders and how they are involved in issues concerning intelligent automation; ii) presents the perceived benefits associated with intelligent automation; iii) presents perceived obstacles and blocking mechanisms towards intelligent automation; iv) discusses external inducement mechanisms to intelligent automation; v) presents the respondents' views on safety and regulation; vi) presents the stakeholders understanding of required knowledge and skills in realizing intelligent automation; vii) discusses human-robot relations and how this collaboration can be made to work in the factories, viii) presents the operators' perspective, ix) discusses factors enabling intelligent automation, and x) discusses the future of intelligent automation in the automotive industry. Both *Chapter 6* and *Chapter 7* discuss the results of the report. *Chapter 6* provides an overview of enabling and blocking mechanisms for intelligent automation, while *Chapter 7* discusses ways forward for enabling intelligent automation as a viable solution for industrial production in the automotive industry.

2. HOW TECHNOLOGY UPGRADE CHANGE WORK AND ORGANIZATION: AN OVERVIEW OF PREVIOUS RESEARCH

In their study of the discourse on "robotization of work" in the social sciences and popular culture, Czarniawska & Joerges recognize a surge in the debate on the consequences of robotization (2020). This is also the case in the Swedish context. A media study conducted by the authors of this report (Larsson and Bengtsson 2022) shows a rapid increase in the use of concepts such as artificial intelligence, cobot, smart automation, and industry 4.0 in the Swedish press. For example, artificial intelligence was used in 69 articles in the 1980s, 170 articles in the 1990s, 926 in the 2000s, and 14112 articles in the 2010s.[3] Although these articles encompass several topics, many articles relate to industrial production. One of the first articles in 1981 (the first year available in the database see footnote 4) mentioning artificial intelligence discusses the prospect of using it in industrial production. The article is an interview with Lars Dahlström, who at the time was responsible for the development of AI at the business company ASEA in Västerås; he is quoted saying that "at the laboratory level, there are very advanced industrial robots that differ significantly from what is available in general use in industry. But the market is not mature [for these robots]". The article continues:

> *Today's robots are not used in the flexible way intended from the beginning, Lars Dahlström says. They are used in many cases for monotone work in long series. Flexibility is not used. The robots are undoubtedly re-programmable, but this is not utilized. Small companies with short production series will benefit the most from using new, more intelligent robots and systems that are now on the way. These companies have not been able to operate today's robots in a sufficiently rational way.*

Dahlström defines intelligent robots as flexible robots with vision and sensors, and "when the robot can adapt to changed conditions." The exciting thing with artificially intelligent robots, according to Dahlström, is that the user should not have to give exact and detailed orders. Dahlström believes that the industry will still need to do precise programming of the robots' tasks for some time ahead. But progressively, more general programming of behavior will be possible. This shows that the topic discussed in this re-

3 Searches have been done in the Retriever database (Mediearkivet), the Nordic region's most prominent digital news archive encompassing news and articles from print and digital editorial media and radio and television from 1981 and onwards. To make the analyzed article easier to compare over time, we have limited the searches to printed media.

port has been discussed for 40 years and that the discourse shows striking similarities to the discussion presented in this report.

More recently, several studies have been published that research primarily technical aspects of the development of technology solutions. Existing scholarship—mainly situated in engineering studies—has considered how AI-driven applications can be made to work within specific industries and health care organizations often performed in a laboratory setting (e.g., Dahl 2021; Erős et al. 2021; James et al. 2013; Jiang et al. 2017). Within engineering studies, there are also several studies on how operators perceive work together with machines and systems that make autonomous decisions or operations perceived as autonomous (e.g., Cramer 2010). These studies on operators' perspectives focus on perceived utility and perceived risk among the operators—some studies also focus on stress by measuring stress levels of operators while operating a specific AI-driven application (e.g., Mattsson et al. 2017).

Within the social sciences, studies of the influence of intelligent automation and AI technology on organizations are scarcer. Given that several of the technologies discussed in this paper are pretty new, there is limited research on organizational aspects of intelligent automation, AI-driven automation, or collaborative robots in organizations. However, while few studies focus on the last generation of AI-driven applications in organizations, there are many studies on the role of technology in organizations (e.g., Cascio and Montealegre 2016; Eriksson-Zetterquist et al. 2011; Barley 2015; Griffith 1999; Laet and Mol 2000; Rafaeli 1986; Zuboff 1988). Organizational studies of technology focus on how technology influences behavior, how it changes vocational roles, and how new technology affects the required skills of workers.

Some of these studies have a cognitivist approach and try to identify general rules for determining under what condition a certain level of automation (commonly referred to as LOA) helps improve the situation awareness and workload for individual operators of the technology in question (e.g., Wright and Kaber 2005). While studies within a cognitivist paradigm can support that type of automation must be tailored for the specific needs to improve the operator's workload, situational awareness, and production in general. They often leave out important factors that determine the functionality of automation in an actual work environment. Perspective underestimates how automation alters not only the execution of a specific task but the organization of work and the nature of work (c.f., Bradshaw et al. 2013).

Other studies have demonstrated that automation might change communication between team members in work settings where human operators have to complete work tasks with the help of an automated system (Johannesen et al. 1994; Wiener 1993). One study showed that automation of information processing decreases communication between pilot and copilot in a collaborative setting because the co-pilot would rather interact with the automation system than the captain (Jentsch and Bowers 1996). Wright and Kaber (2005) investigated how automation influences teamwork regarding team effectiveness and coordination in an experimental setting. The study's findings are that different types of automation affect collaboration differently; for example, the results indicated that automation of decisions leads to better team effectiveness under low levels of task difficulty while simultaneously increasing the workload. The study concluded that automation of acquisition of information and data analysis is most beneficial in the design of team tasks.

Due to the complex and contingent interplay of factors determining the use and functionality of technology in organizations, this body of literature does not provide conclusive results on under what conditions technology can be made to work or how it alters organizations. Furthermore, the various studies' differences in their conclusions can be due to the study designs or differing definitions resulting in that the studies are not always comparable (Wright and Kaber 2005). The studies also diverge in their basic epistemological understanding of, among other things, human cognition (Viktorolius 2020). There are also significant differences between different domains; in aviation automation, it is considered essential to automate tasks that are particularly complex to decrease the complexity of the flight operation (Miller and Parasuraman 2007, 57). In the production industry—which will be demonstrated in this report—it is considered more beneficial to automate easy and repetitive tasks, while some complex assembling tasks might require human operators. Contradictory results might also reflect that the influence of automation in a workplace depends on many factors. The same automation system might be used very differently in two factories depending on several factors, including pre-existing technology (Gherardi 2008), organizational culture, trust, communication, practices, management, and the organizational structure. A study by Viktorolius (2020) convincingly demonstrates how the same automation system is used very differently by the operators in two very similar workplaces (two sister ships) dependent on the previous knowledge of individuals and the group dynamics within crews on the vessels. Automation might change work in ways that are not expected by the designers (Viktorelius 2020).

It is recognized in the previous literature that the views of the benefits of automation vary between stakeholders within organizations and with different positions in society. Miller and Parasuraman (2007, 58) write that "technologists tend to push to automate tasks as fully as possible," which is sometimes referred to as the "technological imperative" (Sheridan 1987). However, human factors engineers and others concerned with safety and the human role in advanced systems have tended to highlight the risks of increased automation (e.g., Perrow 1986; Reason 1997; Woods 1996) and argue against the use of higher levels of automation". The difference between different groups of stakeholders in society regarding the degree of automation is also relevant to this report.

A prominent discussion in the literature is concerned with whether or not (intelligent) automation will reduce the number of available jobs. While some see this as a real threat (e.g., Ericssson 2018; Fölster 2018), others do not see automation as a threat to job opportunities (e.g., Benanav 2020; Fleming 2019). Another topic discussed in the previous scholarly literature is how automation influences operators' skills and knowledge. While automation systems might require some additional skills from the operators, automation is also recognized to deskill workers by automating tasks previously done manually. One early article titled Ironies of automation (Bainbridge 1983) identified that automation might deskill workers and make it more difficult for workers to handle situations where manual intervention is needed. Bainbridge writes: "When manual take-over is needed there is likely to be something wrong with the process so that unusual actions will be needed to control it, and one can argue that the operator needs to be more rather than less skilled, and less rather than more loaded, than average" (Bainbridge 1983, 775). Such deskilling is understood to have possible implications for production and safety. Deskilling has also been discussed in terms of alienation, where the workers become less prone to appreciate their job as fulfilling or meaningful (Donahue 1996).

The way automation is taken up in any work setting might also depend on how the technology is understood to change the nature of work and whether automation is understood to make workers superfluous in the industry. Since the beginning of industrialization, artisans and workers have questioned and resisted the automation of factory work primarily due to a fear of losing one's job. The most famous example is the Luddite movement in the 18th century among textile workers, where a radical fraction would destroy textile machinery in fear of being replaced by machines. Although this is a rare example of a straightforward resistance to technological development, employees' fear of being replaced by machines or having machines take over tasks essential to people's professional identities can be an important factor influencing how automation is perceived, resisted, and adapted to any work setting.

There is also a body of work explicitly studying automation in an organization and how it supposedly changes human practices (e.g., Heath and Luff 2000). In this body of work, it is argued that automation often has unexpected and unintended consequences depending on the lack of recognition by management of the way automation is embedded in the organizational structure (Dourish 2003; Orr 1996). But as argued by Viktorelius et al. 2021 "the literature on automation in work has focused on design and human performance in experimental settings, few studies have investigated the implementation of automation in real work settings." And further research is thus needed into how automation (especially the new generation of intelligent automation) is situated in and alters the organizational setting and work practices. This report is situated in and contributes to this cited research discourse.

3. THEORY: TECHNOLOGY AND HUMANS IN SOCIETY

This study's fundamental theoretical point of departure is a constructivist perspective on organization and technology, which emphasizes that organizations cannot be understood from any ready-made model of organizational hierarchies (Czarniawska 2015). From this perspective, the integration of any new technology is embedded in the social, normative, cultural, and institutional context of the organization in question, making these factors essential to study to understand how any organization operates and adapts to changes. Culture in this regard does not necessarily refer to national or ethnic differences but attitudes, values, and beliefs guiding the action within the organization (e.g., Freedman 1969). From this perspective, the vital thing to study is not how values and beliefs are formulated in policy documents but how they are linked to organizational functions and institutionalized ways of doing things—what might be called "everyday working beliefs" (Beidelman 1984).

More fundamentally, the theoretical perspective of this study assumes that technology has a dialectical relation to human society and human organization. The study departs from the position that all human societies utilize technology, and the way humans use tools separates humans from other mammals (Gibson and Ingold 1994). Development of technology is, from this perspective, understood as a driving force of transformations in human societies and human organization (Nye 2007), and simultaneously human organization, economic structures, and culture enable technical innovations—or make them more difficult, for that matter. The rise of early civilizations is related to the development of technologies, and the contemporary form of liberal democracy is related to industrialization and various inventions such as the steam engine and electricity (Rosenberg and Le 2008).

So, technology is not merely tools or machines, but new technologies might radically alter human societies. For example, anthropologists argue that the Neolithic revolution changed the organization of societies and changed human's conception of nature and the divine (Lévi-Strauss 1966). The introduction of photography, written language—and to take contemporary examples—computers and smartphones—have also altered what it is to be human, i.e., how humans communicate, process knowledge, and the way they organize society and everyday activities at work and at home. While technology has influenced humans and human society through history, technology has a prominent role in contemporary modern society (Heidegger 1993). The progress of society and even sometimes the faith of humanity is entrusted to technology; technology is discussed as the solution to starvation through genetically modified organisms and as a solution to various environmental problems. Also, technological development has been understood to create significant societal problems (e.g., Adorno and Horkheimer 1997) and is increasingly recognized as the root cause of environmental problems. Something that is also characteristic of modern society is a continuous self-reflection about the role of technology in relation to human society, for example, expressed in popular culture.

While technological development is often understood as a cumulative process where continuous improvements build on previous knowledge and solutions, technical development also has paradigmatic ruptures (c.f., Kuhn 1996). The change from steam engines to combustion engines is an example of such a rupture; the steam engines were continually improved until they were replaced with combustion engines. Another example is the mechanical calculators that were replaced by electronic calculators in the 1960s. The manufacturers of mechanical calculators had the machinery and the knowledge of producing state-of-the-art technology that swiftly became obsolete and went out of business, unable to compete with the new technology. Such paradigmatic shifts show that technological development might be cumulative only within a specific paradigm. While new technology, to some extent, will build on previous technical knowledge, new technology will have associated technical challenges that make much of the prior knowledge of technology irrelevant or obsolete. In the context of this report, this discussion is interesting in relation to possible ongoing technology shifts, one being the shift from combustion engines to other types of motors, the other one being a potential shift towards smart or intelligent automation that is sometimes referred to as disruptive in the sense that it might radically alter standards for industrial production.

Furthermore, technological development alters societies and transforms the way humans act and perceive reality; in short, it "transforms what it is to be human" (Feenberg 1999). Clark (2003) argues that this plasticity is something distinctively human and that the human mind is "tailor-made for multiple merges and coalitions" (7) and that the way they integrate technology with the self into human-technology-symbionts is related to the development of language. "Human thought and reason," he argues, "is born out of looping interaction between material brains, material bodies, and complex cultural and technological environments" (11). According to this perspective, humans co-evolve with technological changes, and simultaneously as we "create these supportive environments […], they create us too" (11).

New technology is not only helping people to do things better and faster; it also enables new forms of control (Cascio and Montealegre 2016). The use of technology can alter human behavior intentionally, for instance, through surveillance in a public space. As such, technology is biopolitical in a Foucauldian terminology (Foucault 2007), meaning that technology creates subjectivities or subject positions. Technology can also unintentionally alter/shape human behavior by creating a framework for future action. By working on the subject, technologies make "certain courses of action easier or more difficult" (Li 2007) and as such function to encourage specific behavior. Moreover, technology and legal innovation are co-constitutive:

technology may work as an instrument of optimizing the operations of law (Citron 2008; Kallinikos 2011), yet equally often, legal regulation functions to curtail unwarranted effects of technological innovations seen as disruptive to the established regulatory framework.

Contemporary technology development, including intelligent robots and AI-powered devices, is very likely to significantly impact human organizations, subjectivities, the constitution subject positions (c.f., Laclau and Mouffe 2014), as well as how we view and regulate responsibility. The development of new technology using AI algorithms to make autonomous decisions and human-like interfaces for interactions with humans (such as voice or body language) poses practical, theoretical, and philosophical questions about our understanding of technology and humans. Clark argues, "We humans have always been adept at dovetailing our minds and skills to the shape of our current tools and aids. But when those tools and aids start dovetailing back—when our technologies actively, automatically, and continually tailor themselves to us just as we do to them—then the line between tool and user becomes flimsy indeed […] it becomes harder and harder to say where the world stops, and the person begins" (Clark 2003, 7).

When technology becomes more and more advanced, and the relationship between humans, machines, knowledge, and norms become "flimsy," as Clark formulates it, understanding and evaluating technology in an organization becomes more challenging. The human-technology complex expressed in late modern society and organization can be described as a network of human and non-human actors (Latour 1987). Technology in a contemporary organization has to be studied as such networks or assemblages (Arvidsson 2018; Wise 1997). Many machines and other technical devices function only in a network of other devices, operators, databases, knowledge, and information transfer networks. It also has to be understood in a broader context of regulatory bodies, trade unions, subcontractors and customers studied as a network or assemblage; especially in the technological paradigm referred to as ubiquitous computing, which refers to environments in which computer sensors and other devices are "unified with various objects, people information, and computers, as well as the physical environment" (Cascio and Montealegre 2016, 350).

Although technology shapes human behavior and subjectivities and, to some extent, the course of history, it is also contingent—and the way technology has developed and used is shaped by existing norms, cultural understanding, and ideology. Specific innovations might be resisted for ideological reasons. When used in a new context, they might be adapted to habits and cultural understandings and develop new meanings and uses—as anthropologists, and other researchers have demonstrated in many cases (e.g., Hackett and Lutzenhiser 1985; Viktorolius et al. 2021). Technology is continuously subject to modification during use (Leonardi and Barley 2008), and technology is refuted, or appropriated and used in ways that the developers might not have anticipated; this implicates that integration of new technology must be studied taking the social, cultural and institutional context of the organization into consideration. While stressing the contingency of technological development, previous inventions, technical solutions, standards, and ways of thinking about technology create a framework for possible or somewhat plausible future directions; something commonly referred to as path dependency. Utilizing this theoretical framework will enable an inquiry that "offers rich naturalistic representations of human-automation interaction that accounts for the mutual shaping of human and material agency over time" (Viktorelius et al. 2021).

4. METHOD

4.1 The respondents

The main site for data collection for this report is in-depth interviews conducted with the selected stakeholders. A total of 26 interviews were conducted between January 2019 and Mars 2020. The academia and industry stakeholders were mainly identified in collaboration with a research team at Chalmers Technical University that funded the study. Interviewees within government authorities were selected in consultation with the respective authorities. Taken together, these experts have vast experience of working with these types of issues. Altogether the respondents consist of 8 researchers, 13 respondents from the industry, and five from government and other organizations. The stakeholders are five females and 21 males reflecting a general trend that most engineers and researchers within engineering sciences are men. For further information about the sample profile, see section 6.1. and (**Table 2**). In the report, quotes of the individual respondents will be marked with a randomized three-digit number and a letter indicating their affiliation (I= Industry, U = University, O = Other government body or organization).

Table 1: Sample profile[a]

Item	**Classification**	**N= 26**	
		N	%
Gender	Female	5	24
	Male	21	71
Education[a]	Elementary school	2	
	Secondary school	1	
	Bachelor/Master	5	
	Doctoral degree	9	
Organizational affiliation	University (U)	8	31
	Industry (I)	13	50
	Government and other organizations (O)	5	19

[a] Does not add up to 26 as there are some missing responses to this item.

4.2 The data collection

The first author of this report conducted the interviews. They combined a semi-structured format with open conversations where the respondents were invited to speak freely about the topics of inquiry in this report. In the semi-structured component, some general key questions were asked in the same way in all interviews. These questions were informed by the theory and previous research of this study. The open approach captured each participant's understanding and encouraged reasoning, reaction, and own considerations (Brinkmann 2007; DiCicco-Bloom and Crabtree 2006). Most interviews were done in person, mainly at the respondent's workplace. Due to the current global Covid-19 pandemic, a few interviews were conducted over telephone or video conference calls. All interviews were recorded with the permission of the interviewees. All interviews except one have been done in Swedish. Therefore, the report's authors translated the quotes cited in this report from Swedish to English.

Before the interview, each participant received an information sheet with a summary of the research project's aim and objectives explaining the terms of their participation. Each interview began with asking for explicit consent of recording the interview and to use the collected material for scholarly analysis in line with the aim of the study; they were also informed about their right to cancel participation in the study at any time up till the publication of the study. The interviews lasted between 38 and 200 minutes, with an average of about 90 minutes. The interviews were adjusted to the different categories of interviewees; within government authorities, the interviews were mainly about their perceived role in this technological development, while industry and researchers were asked more specific questions regarding their view on the particular technologies.

Nearly all interviews were conducted in the respective workplace of the respondents, and many respondents gave guided tours in the laboratory (at the university facilities) and the factories in the case of the industry stakeholders. This provided valuable insights when trying to make sense of the statements from the informants.

4.3 Analysis and interpretation

All interviews were transcribed and then inductively coded. The coding of the transcribed material into thematic categories was both open and selective, in line with the basic principles of grounded theory (Corbin and Strauss 1990). This qualitative approach addresses data collection and analysis as interrelated activities. It is based on thematic coding from the basis of common themes identified in the interview material. The interview material was read several times, and codes were formulated through interpretation and comparison within and between interviews (Ryan and Bernard 2003). The result section is divided into thematic areas reflecting the basic categories identified in the empirical material. The headlines in the result section thus correspond to these identified themes.

The empirical data from the interviews have been analyzed by comparing similarities and differences between the interviews and the categories of stakeholders. For further depth to the analysis, the results have been compared with previous research and the theory of the report. The theory and the previous research are not used to create hypotheses to be tested in the study; the role of the theory and research has instead been to identify an area of inquiry and contextualize and deepen the discussion of these topics. To gain some transparency to the analysis and provide an overview of the material, two tables of stakeholders' views on benefits and obstacles associated with intelligent automation are included in the report (**Table 3** and **Table 4**).

The different sections in the report include information from the various categories of stakeholders to a different extent. As the main focus of this report concerns the possibility of implementing smart technology in the industry, the main focus is on the perspective of the industry stakeholders in section 6.2 until 6.4. In these sections, the views of the other stakeholders complement and contextualize the empirical data from the industry stakeholders. The interviews with the stakeholders in government and other organizations have not specifically addressed the benefits and shortcomings of intelligent automation they see but have focused on how it relates to their work and their perspective on how the development of intelligent automation will influence them in their work. The section on human-robot interfaces includes both researchers' and industry stakeholders' views.

4.4 Generalization and limitations

While some of the topics and concerns discussed in this report are specific to the organization of the involved stakeholders, much of the results are possible to generalize to a larger empirical population. Although there will be some differences between different companies and various national regulations and other factors, the analysis of this report would in most regards be representative also for other established manufacturers with complex organizations existing production facilities. However, the conclusions might not represent other industries, where the products manufactured and other variables might create different conditions. For example, intelligent automation might be easier for companies with less product variation and less complex products. The model constructed from this empirical data collection and the general problem area is relevant for many other companies and organizations and is one of the contributions of this study (**Figure 1**). The study is executed in Sweden with Swedish stakeholders. It thus primarily reflects a Swedish and EU regulatory context and the preconditions for making business and investments in relation to Swedish laws and regulations and level of taxation. Still, there are significant similarities throughout the global north, although there will be differences regarding wages, tax, and other factors that will influence the views in those contexts.

5. RESULTS

5.1 Overview of the respondents and their work with intelligent automation

Issues related to intelligent automation and cobots and ATRs in the automotive industry production concern several bodies in Swedish society, including universities, industry, industry organizations, unions, and government agencies. This section contributes knowledge about how these experts are engaged with issues concerning intelligent automation in their professional roles. Mapping these actors and how they relate to each other provides a background for the subsequent sections of the result chapter.

5.1.1 Researchers

The researchers in engineering science that have participated as respondents in this study (n=8) are associated with two different departments at Chalmers University of Technology in Gothenburg, the Department of Electrical Engineering, and the Department of Industrial and Materials Science. The researchers interviewed are three professors, two associate professors, and three doctoral students. Two of the researchers are females, while the other six are male. Their level of formal education is high as they all have a doctorate or study for their doctorate. From their position in academia, they take an interest in intelligent automation in researching and developing state-of-the-art technology. In the interviews, the researchers stressed that intelligent automation could attract research funding for new research projects, offer unique areas of inquiry with results that can be published in scholarly journals, and provide good examples to use in teaching and case studies for student projects. While they have different orientations in their research, it relates to enabling the development of technical applications. The research into intelligent automation includes constructing and evaluating applications, designing control systems to coordinate the actions of several devices, developing mathematical formulas for improving algorithms, and making safety assessments of intelligent automation.

The researchers at Chalmers University of Technology closely collaborate with the industry, especially the automotive industry and have several joint externally funded projects (financed by the government and private research funders). The close collaboration can be highlighted by the fact that one of the Ph.D. students interviews for this project is employed by Volvo GTO. This collaboration with the industry is motivated from the researcher's side by the need for in-kind support for research applications, the importance of using real cases to make research relevant, and a desire to make their research useful to the industry (876r, 953r).

Table 2: The respondents and their affiliation

Respondents	n	How they are involved with intelligent automation
Researchers Engineering Science (r)	8	Developing technology, evaluating technology, developing control systems, developing algorithms, safety assessments, testing and verifying methods, teaching and supervising students, publishing scientific articles, collaboration with the industry
Industry (i)		
Management	8	Standardizing processes, developing technology, research and development, installation of robots and assembly lines, education of operators, standardization of processes, improving processes, technology upgrades and maintenance of equipment
Operators	3	Operating and working with smart machines in production.
Subcontractors	2	Designing and installing robot equipment and assembly lines, training of operators, CE-markings.
Government stakeholders and other organizations (o)	5	Regulation, inspection of work environment, promotion through funding of research and development projects, standardization, education
Total number of respondents (N)	**26**	

5.1.2 Industry

The majority of the industry experts interviewed for this study work in Volvo GTO, a large multinational company with factories in 18 countries worldwide. Most of the respondents from Volvo GTO work in middle management in a broad range of organizational capacities in several departments. These managers have local functions in the factories and global functions within the organization. Their work tasks include, among other things, standardizing processes globally, product development, as well as research and development (**Table 1**). Many of the managers at Volvo GTO have a university degree in engineering (n=6), but some are educated through internal training programs. The study also includes three operators (n=3) within the industry that work or have worked with production in final assembly in Volvo GTO. Two industry experts (n=2) were subcontractors that in different ways work or have worked with Volvo GTO with intelligent automation.

Autonomous solutions at Volvo. ©Volvo Truck Corporation.

Volvo GTO is interested in intelligent automation to improve and streamline its production. They want to evaluate whether or not new technology can be used to create competitive market advantages, for example, by increasing the production capacity of the factories by automating parts of the final assembly that today rely on human manual labor. From the position of Volvo, GTO technological development is essential to keep up with competitors in terms of product quality and affordability of their products. Making technology upgrades involves keeping themselves up-to-date with the current development of technology and doing their research and development. Many of these research and development projects are done in collaboration with technical universities.

While possible benefits in the production are the primary motivating factor for research into and investment in intelligent automation, it also has other motivations. Research and investments are understood to increase the staff's technical competence and create an exciting and attractive workplace for their engineers (488i). One of the respondents within management says: "When we do these things and show that we take contemporary technology development seriously and communicate that to the outside world, we become an attractive employer" (488i). Communicating the research projects together with the company name can also be a way to promote the company's brand (e.g., Fredelius 2016). It is not unusual that companies have technology developments that strengthen their brand even if they are not turned into commercial products (Elish and Boyd 2018, 65). Google's development of AlphaGo is one such example which "engender confidence in the state of a company's technology, help attract technical talent to the company, and help solidify the importance of AI in the future" (Elish and Boyd 2018, 65). Using technology that might be perceived as state-of-the-art in the production process can also potentially be beneficial to the brand value of the final product (348i). This, however, does not seem to be an important motivator for Volvo GTO. A manager within Volvo GTO explicitly stresses a limited interest in technology upgrade of the production among the leadership because these solutions are not directly visible in the final product (931i).

As discussed in the introduction, there is generally a low degree of automation of the final assembly in the automotive industry; this is also true for Volvo GTO (e.g., 154i). The low degree of automation is explained by the considerable variation in their products and the fact that many components are weighty. A manager at Volvo GTO says: "We [in the final assembly] have truck chassis that are up to twelve meters long, making it challenging to bring efficiency in automation. So we still do a lot of the assembly manually" (949i). They also stress that several steps in the assembly process are challenging to automate (this will be discussed in more detail in the coming sections of the report).

A few projects have been initiated within Volvo GTO to evaluate the usefulness of cobots and ATR:s to see if they can increase the degree of automation of final assembly. These projects investigate technical aspects such as how to install them, program them, and explore how communication between humans and robots can be made to work and evaluate the competence needed to handle them without prior knowledge of robotics (949i; 488i; 869i). But their investigations also include how to go about CE-labeling, how to analyze business cases, how to deal with the changes for humans working with this, and how to increase the TRL [4] of the technol-

4 TRL (Technology Readiness Level) or MTR (Manufacturing Readiness Level) are scales for evaluating how developed a certain technology is. The readiness of technology is usually

ogy (593i). A manager at Volvo GTO says that the "reason is partly to learn about the technology and partly to learn how to make risk assessments" (869i). A few of these pilot cases are in the actual production, but the installations are pretty simple from an innovative point of view. One industry stakeholder says, "When we install a collaborative robot, it rarely does any collaborative work. [The advantage is that] we do not have to fence it. But it is scarce for us to find applications where humans and machines can collaborate. It is difficult to say that this technology adds any value, even though we believe it will do so in the future. But the road to getting there is bumpy" (949i). This quote highlights that collaborative robots are used as traditional automation rather than in an innovative or intelligent way (c.f., Michaelis 2020); we will come back to this in the discussion section.

The primary motivation for the current installation from most managers at Volvo GTO is not that they see immediate benefits to the production, but rather to try out and evaluate available technology and see if it is sufficiently developed for future investments. One person in management said that much of the work related to technology development in the factories is to prove that available cobots and ATRs aren't sufficiently suitable (949i)—in other words, to be the devil's advocate for new technology. Managers recognize the need to keep up with the latest development: "You could say that we are exploring the technology, but we do not implement it [on a large scale] if we do not see profitability. We can run individual prototypes or cells where we do so without seeing profitability, but on the whole, we need to see the benefits of technology to invest in it" (949i). As it stands today, there is no plan for any large-scale investments in such technology (973i; 942i). So rather than having to focus on implementing it in production research into these technologies is considered important "since it is a new area developing rapidly, we see that we must be at the forefront […] to influence the direction, [and] to be able to implement this quickly" (488i). These pilot cases are understood as a learning process to identify possible uses and deal with safety evaluations.

Managers recognize the need to keep up with technological development. And express a worry about not being able to keep up with the development in the industry and that their production and products might become obsolete. A manager at Volvo GTO (593i) says:

> *And especially if we are not ready to adjust. We talk a lot about the next generation of products. If we only keep doing combustion engines, we might be outrivaled by competitors; there are many such examples throughout history.*

In other words, some managers recognize that future changes might be very rapid and comparable to other paradigmatic shifts throughout history;

measured on a scale from 1–9 or 1–10. This way of talking about technology was originally developed by NASA during the 1970s using a scale from 1 to 7. TRL and MTR are concepts that are frequently mentioned by the industry stakeholders.

this is a motivation for keeping up to speed with current trends in innovation.

In discussing future trends, managers recognize shorter product cycles and increased diversification of products, but the most critical coming change concerns the future of the propulsion system. However, the people interviewed for this study stress that the exact nature of future development is hard to predict. While electrification is a significant trend in the automotive industry, much talks against such a development. A manager within Volvo GTO (593i) stressed that a truck with a short distance reach would need batteries weighing three or four tons and says:

> *It is not certain that [future development] is just about electrification. We here at Volvo talk a lot about electrification. But who knows—the fuel cell technology might take a leap? Some kind of hybrid solution might also be relevant in the future.*

Another manager points out that the societal actors might conclude that eco diesel will be the preferable environmentally friendly choice after all. Furthermore, this same manager recognizes that the time span of possible future electrification is hard to foresee: "if there is going to be a transformation towards electric vehicles, this transition might take 30 years rather than 5" (593i). According to this manager, the development will be influenced by political decisions, especially regarding environmental regulation:

> *The future depends on to what extent environmental requirements will be allowed to set the agenda. A strictly formulated directive might suddenly come stipulating that "no, you must not use this type of fuel anymore," or "you must not have exhaust emissions over this and that level." […] I'm taking part in the debate, and I'm looking at tomorrow's products and investigating how they could be incorporated into our production. Still, I feel like I'm peeking through a small hole—I do not see the whole picture. (593i).*

The future of the propulsion system is essential for decisions on investments in manufacturing technology and automation because different engines are understood to be differently complex to assemble and require additional equipment and different ways of designing the factories and organizing work.

Although the focus of this study, regarding the choice of industry stakeholder, is Volvo GTO, they rely on robot integrators and other subcontractors to facilitate many installations and, in the case of collaborative applications, sometimes also the CE-labeling. The subcontractors included in this study (n=2) represent one small start-up company exclusively working with flexible automation. The other is an integrator that mainly focuses on traditional automation and makes robot installation with cobots and ATRs. Both these actors see potential in intelligent automation, cobots, and ATRs, but stress that there is generally relatively small interest in cobots and ATRs (887i). They both say that it is more common for small to medium-sized companies to invest in cobots. Larger companies rely on well-established solutions for manufacturing and are reluctant to try new technology that is not adequately evaluated.

One subcontractor focusing solely on flexible automation understands it to be a way of adjusting production to deal with swift changes in production caused by fluctuation in product demand or necessary changes due to other circumstances. This stakeholder describes intelligent and flexible automation as "low-risk automation" (348i) or agile automation and views these new technologies as a way to deal with risk in technology investments stating that "[cobots has] the benefits of lower risks, and the possibility of faster adjustment of production" (348i). Cobots, he argues, have a relatively low investment cost, and the robots are possible to reprogram for different tasks depending on the current requirements of the company. However, he recognizes that introducing such automation might be a challenge to the organization. For example, he argues that these solutions have to be introduced and implemented from the top-down rather than from the bottom up because it involves coordination between the various departments in the factory (348i).

5.1.3 Government agencies and other organizations

This study also includes four respondents from three Swedish government authorities, the *Swedish Agency for Economic and Regional Growth* (*Tillväxtverket*), a Swedish authority working to promote development and economic growth, *Vinnova* (*Sweden's innovation agency*), and the *Swedish Work Environment Authority* (*Arbetsmiljöverket*). While the first two work with promoting innovation, the third work with regulating technology and ensuring the safe use of machines and robots. The Swedish Work Environment Authority's role is to work with intelligent automation from a work environment and safety perspective. The stakeholder working at Tillväxtverket recognizes that Sweden has a comparatively low level of automation compared to many other European countries and underlines that support of intelligent automation relates to the goal that Sweden should keep up with the global competition in technological development (222o). The stakeholder working at Vinnova says that they have supported many innovation projects to develop and assess collaborative projects in industrial settings (399o). The study also included a representative of the Swedish Institute for Standards (SiS), the Swedish branch of the International Organization for Standardization. This organization is involved in producing and publishing standards, among other things relevant to the development of intelligent automation.

5.2 Perceived benefits and inducement mechanisms

5.2.1 Ergonomics, quality, and safety

When asked about the benefit of intelligent automation in final assembly, researchers and industry stakeholders stress that workplace ergonomics is the most important reason to invest in cobots and ATRs. This includes improving working conditions by making robots assist in heavy lifting and removing repetitive work tasks. A manager within Volvo GTO says that: "ergonomics is number one, it is the most important thing when we are looking for a place [that is suitable for cobots automation], if there is poor quality in the production and at the same time poor ergonomics—the two are usually connected—then these are the places we choose" (154i). As demonstrated by the quote, quality and ergonomics are understood to be interconnected. So, an improvement of ergonomics will consequently also improve the quality of the product.

Improved quality is also discussed as a benefit of automation using cobots and ATRs in itself (without relating to ergonomics). Improvement of quality is understood to make the production more cost-effective as it will decrease the number of products that have to be remade or discarded. Another important benefit that is stressed by several of the informants is increased safety by "removing work tasks that are potentially harmful to the operator" (942i). Increased safety is especially talked about in relation to installing ATRs (often referred to by the informants as automated guided carts or abbreviated as AGC:s) as a replacement of human-operated trucks and forklifts—but it is also understood as an important reason to install cobots. Furthermore, an often-cited benefit is that it removes boring and repetitive jobs.

Table 3: Reasons to invest in cobots and ATRs in the factory

Reasons	N	Example quote
Improve ergonomics	154i; 942i; 869i; 488i; 593i; 973i; 491i; 274i; 222o; 205o: 953i; 931i; 348i; 477r; 568r; 876r; 378r; 295r	"Ergonomics is number one when we try to identify potential places [to install cobots]" (154i).
Improve quality	154i; 942i; 973i; 931i; 348i; 876r; 378r; 295r	"...good things to automate are, for example, glue operations, it is a very difficult and time-consuming job, and a job where the operators tend to make mistakes" (931i).
Improve quality	154i; 942i; 973i; 931i; 348i; 876r; 378r; 295r	"...good things to automate are, for example, glue operations, it is a very difficult and time-consuming job, and a job where the operators tend to make mistakes" (931i).
Increase safety	154i; 942i; 635i; 491i; 274i; 390o	"If it is a heavily trafficked truck aisle, it is usually better to send out an automated vehicle that crosses than for a person to cross" (942i).
Remove boring or monotonous work tasks	869i; 973i; 348i; 593i; 222o, 491i; 274i;	"There are major uses for [cobots] in the future. One should aim for heavy monotonous jobs [when deciding places to automate]" (274i).
Save space in comparison to traditional automation	488i; 348i; 154i; 722r	"We can place [cobots] anywhere […] they hardly take up any space" (488i).

Reasons	N	Example quote
Make production more flexible	949i; 488i; 887i; 348i; 222o; 876r; 295r	"Due to the fact that these robots don't need to be within a fenced area, we gain some flexibility. […] A robot of this type can be used as a lifting tool, or to assemble certain things […], and if we learn how to program it in a good way, it can become a flexible tool" (488i). "If there is a large variation between products [produced in the same assembly line], they can take different lengths of time to assemble at each station. A product that takes a long time stops the entire production line. [...] If you can plug in some robots, and plug them out and plug them in another place to even out the balance at the station [...] then you can have production lines that handle greater variation" (876r). "We already have carts that go on coils, but the goal is to be able to make it a more flexible process in the future. That you should have a group of carts that together solve a larger assignment, make a pick up where there is a need, and deliver where there is a need" (942i).
Balance flow of production	869i; 488i; 348i; 154i	"So, we imagine that these robots will also help us handle pikes at the different stations instead of having 50 percent over staff, just to be able to handle those pikes by using a mobile cobot" (488i).
Coordinating work tasks	949i	"[ATRs] for different types of transport is a very interesting solution. Partly to run point to point, but also to look at more flexible systems. You have a fleet of AGCs that go around and perform various missions." (949i).

Reasons	N	Example quote
Innovative uses	593i; 488i; 568r; 378r; 722r	"[ATRs] for different types of transport is a very interesting solution. Partly to run point to point, but also to look at more flexible systems. You have a fleet of AGCs that go around and perform various missions." (949i).
Innovative uses Reduce reliance on human workers	488i; 973i; 154i; 348i; 491i; 274i; 953r; 222o; 378r; 722r;	"We have a problem recruiting competent and motivated staff to our factories […] we need more machines that can do a part of the work" (488i). "The thing you can avoid with automation are these union aspects, i.e., the discussions with the union when you have to cut back on people or change rates or things like that" (973i). "A machine operator is quite expensive, so instead of making him load and unload the machine, a robot can do it, and the operator can monitor" (378r).

5.2.2 Flexibility and coordination of work tasks

Another mentioned potential benefit of cobots and ATRs is the prospect of increasing flexibility in the production. It is stressed by many of the respondents that cobots, as well as ATRs, are easier to program compared to traditional automation, and the applications such as cobots can be moved between workstations and be used as tools for various purposes. Another thing that is stressed is that they require very little space in the factories and that they, in many cases, can be used in existing workstations in existing factories. An area of use of cobots, suggested by the interviewed industry stakeholders and researchers, is to balance differences in the production time of different products. The workstations on the mainline of the factory have a station time where the operator needs to finalize the operations (931i), and some of the specialized low volume products might exceed the maximum time limit for a workstation (869i). Adding robots that could be moved between different workstations could be used to balance the flow in the production and avoid stops (722r; 876r). However, it is stressed by other industry stakeholders within Volvo GTO that this is a solution that might be good in theory, but that is very difficult to achieve in practice (869i).

Another possible benefit that relates to flexibility discussed by the industry stakeholders and the researchers is the prospect of using several collaborative robots, humans, sensors, and conveyors to efficiently coordinate work tasks. For example, a manager says:

> *[W]ith the help of [ATRs] that make sure that all material and all tools are in the right place at the right time. We could design a line without tools, materials, or anything, but we can make it available when needed […]. We see a huge potential in these systems. (949i)*

Such a system, it is argued, could make the production more flexible, and a system of coordinated robots and devices could be programmed to continue to operate even if one of the machines failed to operate.

However, the industry stakeholders do not understand cobots and ATRs as a solution to make production more resilient to swift changes in products or fluctuation in demand as manufacturers of such robots do. On the contrary, when the industrial stakeholders talk about good places to utilize intelligent automation, they stress the importance of choosing sites with low product variability to make automation possible. This stands in contrast with the discourse that these machines would be flexible in the sense that they can deal with product variability. The difficulty in achieving desired flexibility is highlighted by this quote of a government stakeholder (222o):

> *Since the dawn of industrial robots, people have said that robots are flexible. You can do anything with them: you can assemble, glue, weld, […] Yes, that is true. But when you have built a welding robot, it will only be a welding robot. [...]. What is needed is a flexible machine that can continue being flexible.*

So, the flexibility of cobots and ATRs is often related to the fact that they can be easily programmed and moved around in some cases. While this can motivate small businesses to invest in cobots to change the robot program for each production batch, it might not be a viable solution for large automotive companies like Volvo GTO. This is because the production system, products, and tasks to perform are very complex and require a truly flexible system without manually changing the robot program. For cobots and ATRs to become helpful in the production of a large company with high volume production, they cannot be used simply as individual robots, but it requires intelligent ways of designing workstations and intelligent coordination of tasks between humans and machines. We will return to this discussion in Chapter 7.

5.2.4 Automated support for operators and innovative uses of intelligent technology

Several respondents, both from within the industry and academia, stressed that intelligent automation could provide cognitive support systems. A manager at Volvo GTO says that "[a] lot of automation is for supporting humans, that is, different information systems [will be] very important to us" (949i). Another manager (973i) gives an example of how such a cognitive support system could work in practice:

> *There are also solutions where you use gloves and other tools. If the operator sees a frame in front of him where he has to attach several different brackets, this glove could help him find the correct hole pattern because if you imagine a whole frame with X number of holes, you should see the correct hole pattern for the truck. I think such solutions can be beneficial. Where there are many choices for the operator to make in both X- and Y-joints [...], it will be a valuable tool for the operator. It will also ensure quality.*

Some of the respondents within the industry understand applications for cognitive support to be the most important area for intelligent automation in the near future (949i). With devices like gloves, vests, or goggles with augmented reality projections, the operator can provide updated details about the production process and instructions for work tasks. These forms of support systems, it is argued, could also be used as support for doing tasks on the computer, for example, for assisting the engineers working with preparation processes for the manufacturing, by giving suggestions based on a shared information system (949i).

In discussing potential benefits, some respondents also stress possible uses that are not filling a function that exists today. One suggestion for an innovative use is to use the robot as a "gym machine" (488i). "If there is a stop in the line, you can use it for training. We might also find new innovative ways of using these flexible robots in a good way". Another researcher suggested that the robots could have a social function to communicate with the operator to achieve a better work environment (568i).

Yet another example of innovative use of cobots in the pre-assembly stations is to use collaborative robots to reduce the work pace and thus the level of stress among operators and increase the quality in production:

> *We have a problem in the production in the pre-assembly station that makes modules to be mounted on the chassis of the mainline. The operators work very quickly to create a time buffer to get some time to rest. But this way of work-*

> *ing is bad from an ergonomic point of view, and it becomes stressful for the operators, and the quality is suffering because they tend to take shortcuts. But if you worked with a collaborative robot, it could set the pace for the operator's work. If the human works together with a robot, the human would need to slow down his work pace because the robot is continuously doing the work at a certain pace. So basically, the robot would control that you have a steady pace, and there is no point in working faster because the robot works at its own pace. (931i)*

While making this suggestion, the respondent also said that some of their tests have shown that operators might perceive increased stress when waiting for the robot to perform a task—but say that this is a matter of habit. Another manager does not understand such solutions as beneficial and says that a system should never be designed so that the human has to wait for the robot to perform a task as that will create too much frustration. A researcher expressed a similar view to this latter manager stating: "I think you have to design the system so that it is easy for the operator to continue to do the same thing—and get the system to adapt. If you make the operator sort out complex situations, I think he will get exhausted quickly" (477r).

5.2.5 Reduce the number of human workers

Although not so often explicitly expressed in the interviews, an underlying assumption is that a potential benefit of intelligent automation could be a streamlined production and a reduced number of operators, which would make the production cheaper. This would make the company more competitive in relation to other companies and make the individual factories competitive in relation to other existing factories within the same business company or potential new factories in low-income countries. Given the current global competition, one of the managers within Volvo GTO said that "the amount of manual labor must decrease—I believe that it is our way of keeping up in the competition with low-wage countries" (593i). It can also be seen in the quote in **Table 3** that some respondents explicitly talk about the benefit of staff reduction in relation to intelligent automation. Sometimes this is spoken of as a way of reducing costs, but it is also talked about as a necessity based on the difficulties in recruiting competent staff.

One of the managers stressed that a reduction in the number of employees would also save time and energy by avoiding negotiation with the unions; an industry stakeholder says, "the thing you can avoid with automation are these union aspects, i.e., the discussions with the union when you have to cut back on people or change rates or things like that" (973i). Another manager argued that a change from human operators to robots would make the competition more even with other European countries with lower wages and different regulations, union agreements, and government policies. An operator says: "It is also noticeable that there are different regulations in the different European countries. France and even Belgium have completely different agreements on how they can bring in staff, and we often compete against each other. You can avoid this with more automated solutions" (593i).

5.2.6 Good cases for intelligent automation, suitable places to automate

Some of the potential benefits of intelligent and flexible automation discussed above are understood to be quite far from implementation. Still, there are also uses of cobots and ATR that are understood to be possible to introduce now or in the near future. These solutions are not intelligent to any actual extent, but rather traditional automation solutions using cobots and ATR automate certain operations. A manager at Volvo GTO (942i) says:

> *You choose stations to automate where it fulfills a specific purpose. [...] I think one should focus on the areas where quality and ergonomics can be improved, stations where an automated process can do something better than a human being. That can be operations that are potentially harmful to humans or something that humans often do wrong. There, I believe the significant gains are in the coming years.*

It is understood to be essential to select operations where product variability is low (154i), where ergonomics is poor, and where for some reason the product quality is low (973i), as well as time-consuming operations where the operators often make mistakes (931i). Managers understand it to be easier to automate the sub-flows and the transport between workstations compared to the mainline. The sub-flows are preferable to the mainline because they do not have fixed time slots. In contrast, cobots and ATRs are generally understood as challenging to introduce in the main production line due to the need for speed and accuracy (949v). Choosing places with little connection to the overall IT structure is also considered preferable. A manager in Volvo GTO says: "In a large company like ours with our IT structure, it will be an extensive project to change something within the IT structure. So, I think you should start with fairly simple automation that may not need much connection to the IT structure" (942i).

Suggestions for specific operations that are considered easier to automate are: "various gluing operations" (931i) and tightening of screws and bolts (593i). Another area thought suitable for automation is inspection or quality control (154i; 876r). This can be through vision systems using image recognition software examining the product, or cameras registering the movement of the operator to try to decide the probability of a correct installation (488i), or robots that physically check the quality of the manufactured product, for example by checking if bolts are correctly tightened. Another operation considered suitable for automation within the near future is moving items from the pre-assembly to the main production line using ATRs (931i). Using a vision system with AI-driven image recognition for pick and place operations is also an intelligent solution that some managers see as a possible future solution for the factories. A manager at Volvo GTO says: "There have been some interesting experiments with software and cameras—you analyze an image, and then you pick and place the article. I think we will see a great development of this in the future" (593i). It is recognized that one cannot only focus on speed when evaluating the benefits of intelligent automation. A researcher says: "If it takes half a minute longer to complete an operation [with automation], compared to a human operator, you might improve the quality or reduce sick leave because the ergonomic problems are reduced [...] you cannot just look at the time aspect when making investment calculations" (378r).

However, as discussed previously, there are significant differences between the involved stakeholders regarding the perceived benefits of cobots and ATRs. While many informants talk about the benefits of collaborative automation, one researcher explicitly says that this is a dead-end. While understanding flexible automation, intelligent vision systems, more and better sensors, flexible grippers, machine learning to have huge potential in the future, this researcher does not see human-robot collaboration as a good option. Similarly, a stakeholder at Volvo GTO says: "I would say that the collaborative aspect [human-robot-interaction] of automation is not as interesting to us as making the production cells more autonomous and smarter" (949i). Two researchers say that every task could be automated, and respondents at Volvo GTO agreed that full automation is possible in theory: "well, maybe some tasks are too difficult to automate today. Let's take entering screws, for example. But if you change the product's construction, you will not need screws; you could design the product so that the parts are attached through a weld rather than with screws or bolts" (593i).

When it comes to potential benefits associated with intelligent automation, the answers from the industry stakeholders and the researchers are very similar. The researchers are sometimes more elaborate in discussing the possibilities of AI-driven coordination of applications and other more innovative solutions, but otherwise, they have essentially the same outlook. The benefits of intelligent automation stressed by the stakeholders in this study are similar to those emphasized in robot manufacturers' marketing of these products. The similarities in responses indicate that these views are influenced by a shared discursive field (way of talking about things) rather than through the actors' own experience of such benefits.

5.3 Perceived obstacles and blocking mechanisms

5.3.1 Technical obstacles

As discussed in the section above, nearly all the respondents stressed the potential benefits of cobots and ATRs. However, those working in management in Volvo GTO are hesitant to introduce such solutions into production in final assembly. **Table 4** provides an overview of perceived obstacles divided into internal and external blocking mechanisms. A critical internal blocking mechanism related to technology is that their products are not designed for automation. Many components are said to be too heavy for utilizing the relatively small collaborative robots and ATRs. These robots cannot handle the same weight or operate at the same speed as a regular robot. A manager at Volvo GTO says: "When you manufacture trucks, the components and parts become very heavy for a co-bot. They are rather slow for safety reasons since they should be used in environments with humans" (949i). In other words, the technology in question is not understood to be adjusted to their product.

When it comes to external blocking mechanisms involving technology, the shortcomings of commercially available robots and equipment is understood to be a significant obstacle. For example, many respondents claim that the available products are not sufficiently well developed for their needs. One of the managers at Volvo GTO (154i) says:

> *Many suppliers show flashy products, but it is early in their development phase, and to be honest, they are only prototypes if you look closer. Even those so-called cobots or co-existing robots that have been around for a few years lack the security systems needed for us to feel confident enough to make them work together with a human being.*

Other things said to be insufficiently developed for industrial production are grippers, vision systems, and laser scanners (949i).

When talking about how technology is not sufficiently well developed, it is not always that the technology makes it impossible to automate certain operations but that these solutions are understood to be too slow or too expensive. A manager at Volvo GTO says that the rapid production pace in their production requires a very high degree of accuracy: "it is not enough that it can deal with 70–80 percent of the situations, it has to be able to deal with 99,9 percent of the situations successfully; otherwise we would still need humans [to correct the mistakes]" (949i). Consequently, a relatively high degree of mistakes requires too much staffing to make a system run smoothly. Another blocking mechanism discussed in the interviews relating to technology is the lack of competent staff to deal with cobots, ATRs, or intelligent automation systems, both within and outside the factory (see **Table 4**).

Researchers also stress limitations in speed and other difficulties in making cobots, ATRs, and intelligent automation work well in an industrial setting but are generally more positive. The differences between the industry experts and the researchers in this regard can be explained by the fact that researchers evaluate technological solutions in a laboratory or an experimental setting. On the other hand, the industry experts must ensure that these solutions work in an industrial environment for a long time. The management of Volvo GTO has to consider more than only the technical aspects when investing in new technology. Another part of this difference in experience is that researchers usually develop and evaluate technology that may not be available for use in factories in the immediate future.

5.3.2 Compatibility between new and old technology

While expressing dissatisfaction with currently available cobots, one of the managers at Volvo GTO takes a deep breath and adds that he maybe should not complain too much about the technology not being mature enough, "maybe it is us who are not mature enough. Maybe the technology exists, maybe it is us who should learn to adopt the technology" (593i). Several challenges in adopting new technology relate to making it compatible with existing technology and finding new ways to make the technological solutions work well with current technology, infrastructure, and established ways of doing things.

Technical challenges do not only relate to the performance of available cobots, ATRs, and other machines and equipment that are bought, but also to how this equipment can be made to work together with the existing equipment (869i). So, several challenges related to installing intelligent automation are not directly related to the equipment or robots themselves but the way they function with existing technology in the factories. Another manager expresses the same viewpoint when stating that "[i]t is complex to introduce [intelligent automation] in already existing processes" (942i). A large manufacturer like Volvo GTO has existing production, limited space in factories, and significant investments in technology due to the company's history. A manager at Volvo GTO says: "If we were to build a completely new factory without having our backpack of IT systems and other equipment, it would look completely different than it does today. But we have a history we work with; we also have factories from different histories, so we have old systems that remain since before Volvo acquired them" (942i).

One perceived obstacle regarding the compatibility with existing equipment is the IT system and the prospect of transferring information between different units in the factory. This includes difficulties in transferring data from one place to another. For example, getting 3D representations of the products to the preparation process, or for that matter, to a robot (949i). Another manager at Volvo GTO (154i) says:

> *We want to be able to feed [the robot] with the databases we have today to provide information on the article and the variations and then send it directly to the robot. Still, you often have to write a unique program in each case to facilitate this, which becomes very costly.*

Another difficulty that management stresses in the factories are the lack of common standards for devices from different manufacturers today. A manager at Volvo GTO says: "We have to be very careful when we buy machines because they are all different, every brand is using their way of programming, we would like to see a common standard" (154i). Consequently, there is a perceived compatibility problem between new and old technology and between different brands of new technology that can be used for intelligent automation.

The problems with compatibility between the existing machines and the collaborative robots have become evident in one of the ongoing projects in one of the factories. A cobot has been installed in a station with the task of attaching a toric joint to a small metal pipe. However, the machine that bends the pipes is not so precise and produces pipes with slightly different angles (869i). An operator says, "because the machine is a few years old, the interoperability between the robot and the packing machine does not always work very well" (491i). While it is easy for a human to compensate for the differences between the pipes when attaching the toric joint, it is difficult to program the robot to deal with these variations, especially when only using the control system of the robot and not an adaptive control system often used for intelligent automation. While the collaborative robot is said to be working well, the existing equipment creates problems in the overall process (593i).

Another perceived obstacle related to technology compatibility is the ability to locate the product for the robot to work on. One of the factories visited for this study uses an automated guided vehicle that navigates on an induction coil. A manager in one of the factories (869i) says that the precision is too low at every stop, making it challenging to use robots.

In the final assembly, we have many repetitive work tasks. […] The problem is that we do not know the object's exact position. We get the position when the object enters the station, and that position has an error margin of maybe plus-minus two centimeters. But plus-minus two centimeters when you use a socket wrench that accepts an error margin of maybe plus-minus two millimeters will not work, and we will get a disturbance in the workflow. That is the major problem in a final assembly where we need accuracy in positioning. Otherwise, it would work. […] This is not the robot's fault but rather a problem related to the other equipment.

One of the managers compares the conditions for automation in their factory to a Renault factory they visited in France, a factory where they have successfully installed some 50 cobots. The manager said in the interview that it is much more difficult to introduce such technology in the final assembly in the Volvo GTO factory compared to the Renault factory. In the Renault factory, the manager explained, they use a conveyor belt in the assembly line in contrast to the AGV trucks (operated on an induction coil) that drive the line in the Volvo GTO factories. "They had indexed stops so […] they had excellent precision in the positioning […] Not like here where the AGV has a very rough positioning". In other words, they understand the problem in identifying objects related to the existing technology in the factory.

Technological obstacles to increased automation also relate to how the products are designed (973i). Attaching cables alongside the frames in the chassis and other such tasks are considered hard to automate; even finding semi-automated or hybrid solutions involving both humans and robots, given the current product design, is hard. A manager says: "The construction department must make a product, that is, how should I put it? 'Robot-friendly'" (973i). A robot-friendly product is designed to make it easier for a robot to handle (this can include making the parts used in the production more accessible to grip by a robot arm or using riveting instead of screws). Also, how the components are packaged has to be done so that a robot can unpack them and grip them (869i). In short, the product is not adapted to automation, both regarding grip points and precision (942i). To enable automation of a larger part of the final assembly, there have to be changes involving several departments within the organization—including the product design section, preparation process, and production (488i).

The large product variability is one of the most frequently mentioned internal blocking mechanisms for automating the final assembly (Table 4). One manager in Volvo GTO said they "have a considerable variation between our products. That makes it difficult to describe the products in a way that enables the robot to work with it" (942i). Another manager (593i) explicitly states this as the most important reason:

> *The number of variants places high demands on an automation cell. And that's probably what has hindered the automation, really, in the final assembly. Because there are many tasks, you could automate there as well. But it gets complex, and it gets expensive.*

Another internal blocking mechanism is the difficulty in balancing the workload between humans and robots so that the capacity of the humans and the automation can be used to the fullest. A stakeholder at Volvo GTO says: "It is difficult to combine automation with manual work […]in terms of time and balancing. A machine is a machine. It works at the pace at which it has been programmed; an operator can be flexible when he sees that the workload increases" (593i). Again, this shows that managers at Volvo GTO do not envision automation that is intelligent in the sense that it can be flexible and adaptable to circumstances.

When discussing how technical obstacles make it challenging to introduce automation, the problem is not always that it is impossible to automate, but that some things are too expensive to automate, or that automation is understood to be too slow to make the production processes efficient. "In theory, the robot could find a screw head using vision-based sensors; the problem is that it is very time-consuming […] and time is money" (869i). So even if automation could be made flexible with intelligent automation, such automation is considered by many of the respondents to be too time-consuming and would slow down the flow in the production. Both among researchers and industry experts, some of the respondents emphasize that in theory "[e]verything can be done with automation" (c.f., 869i)—but that it is not always cost-effective or that it requires changes in the way products are designed.

Table 4: Blocking mechanisms for intelligent automation

Perceived obstacles for intelligent automation	N	Example quotes
External blocking mechanisms		
Available robots and equipment are not sufficiently good	154i; 949i; 154i; 593i; 973i; 869i	"…the products do not exist, either the grippers are not available, or the product is simply a prototype […] when you start looking at what they call a collaborative robot there are a lot of safety features missing, or the programming may not be complete even if the hardware itself is and so on" (154i). "The available [ATRs] are not well equipped for industrial use" (593i).
Regulation and safety standards	949i; 942i; 869i; 593i; 488i; 154i; 887i; 348i; 399o; 205o; 783o; 660r 953r; 477r; 568r; 876r; 722r; 295r	"...the standards for safety are very rigid and not adjusted to small flexible installations" (942i) "I do not feel that current standards promote collaborative robots or collaborative systems" (869i).

Perceived obstacles for intelligent automation	N	Example quotes
Lack of competency in dealing with cobots and ATR:s	949i; 931i; 869i; 348i; 378r	"Given that collaborative robots is a fairly new area, there are quite a few companies that certify stations with collaborative robots" (378r). "It's not that much competency in this field [of intelligent automation] compared to traditional automation. In principle, each municipality has one or more automation companies, which can solve, more or less, most problems. But that is not the case with intelligent automation" (348i).
Internal blocking mechanisms		
Difficulties to coordinate with current IT-systems and flow of information in the factory.	869i; 887i; 154i;	"We want to be able to feed [the robot] with the databases we have today, to provide information on the article and the variations and then send it directly to the robot, but often you have to write a special program in each case to facilitate this, and it becomes very costly" (154i).
Incompatibility with existing machines and equipment in the factory.	593i; 869i; 942i; 973i; 154i	"We get the position when the object enters the station and that position has an error margin of maybe plus-minus two centimeters. But plus-minus two centimeters when you use a socket wrench that accepts an error margin of maybe plus-minus two millimeters, that will not work, and we will get a disturbance in the workflow" (869i).
Too large variation in products	949i; 942i; 869i; 931i; 593i; 953i; 154i	"We don't mass-produce vehicles but rather build customized machines for each customer. […] So, each product is unique and therefore it is difficult for us [...] to automate our production" (949i). "In order for it to be possible to do it at all, there needs to be a fairly low variation between the products, otherwise it will be very difficult to tell the robot what to do" (154i).

Perceived obstacles for intelligent automation	N	Example quotes
Difficult to balance workload at work stations with humans and cobots.	593i; 154i; 295r	"It is difficult to combine automation with manual work […] both in terms of time and balancing. A machine is a machine. It works at the pace at which it has been programmed, an operator can be flexible when he sees that the workload increases" (593i). "In a station with both robots and human operators — who does what? We want to use the robot for what they are best at, and human operators for what they are best at. But still, there are many operations that both the robot and the human can do, so who does what in assembly tasks" (295r)?
Products not designed for automation	154i; 953i; 973i; 949i; 931i; 593i; 488i; 876r; 378r; 295r; 222o;	"Usually, the product is not designed for automation. A product has usually been designed so that a human can mount it but not a robot. Assembly often requires you to hold something, and at the same time put on something else [...] We usually say 'automate the tasks that you can do with one hand'" (378r). "You need a product that is designed for automation to be able to automate efficiently" (154i). "We have a lot of manual work due to the fact that we have such complex products" (593i). "...the preparation process for us will be a challenge, because within the final assembly we are not used to working with automation. That is, the product is not designed for automation, for example regarding grip points, and other aspects. The product is designed to be assembled manually, and making it automated becomes a challenge" (942i).

Perceived obstacles for intelligent automation	N	Example quotes
Lack of acceptability among staff	931v; 973v; 348i; 488i; 477r; 876r; 295r	"it is a challenge for us to create acceptability among the operators" (931i)
Concerns over safety	949i; 274i; 973i; 660r; 876r; 378r; 295r; 399o; 205o; 390o; 783o;	"it is tricky when a robot works with a human, how to solve it so that it becomes safe for the people who work with the robot" (390o)? "If I hit my colleague with my tool when I turn around, it's okay, but if the cobot does the same thing [...] we will probably see a witch hunt" (949i).
Insufficient proof that benefits will exceed investments	949i; 154i; 942i; 973i, 869i; 154i; 295r	"Cobots are expensive [...] As it is today, these installations are not profitable, we cannot recoup the investments" (154i). "Theoretically you can automate the final assembly with [intelligent] automation, but the installations will be slow, and time is money" (869i).
Previous bad experiences	348i; 154i; 931i; 953r	"It is clear that many of these industries have made some attempts here and there, and that it has turned out to be complicated. They still had to use a human operator to grind away something with an angle grinder or something similar because the robot could not access it. Such things have happened to them too many times over the years" (953r) "People rarely say that their technology investment was a complete failure, then you disqualify your own judgment. But if you have bought a robot and aren't satisfied with the results, you will probably not buy another one" (348i)

Perceived obstacles for intelligent automation	N	Example quotes
Organization	973i; 348i; 942i; 953r; 378r	"The technology exists, and is quite well developed. The available technology with collaborative robots works perfectly well to implement. I think the challenge lies more in the organizational structure [of the company] than in the technology" (378r). "Maybe it is we who are not mature enough. Maybe technology exists. Maybe it is we who should learn to adopt the technology" (593i). "I [as a researcher] only see the technical issues, but [the industry] have issues related to management, the trade unions, and dealing with people in the organization" (953r).

5.3.2 Organizational obstacles

Another obstacle in introducing cobots, ATRs, and intelligent automation in Volvo GTO is the way any large company is organized. In the case of a large-scale implementation of these technologies, there are several organizational matters to address—and many choices to be made regarding how to deal with this in the organization. First of all, it is considered difficult to coordinate work tasks between robots and humans. If intelligent automation is used, where pace and assignments are flexible, the coordination of tasks will be challenging to design due to a lack of experience and competence in the organization. It is also considered a challenge to divide work and responsibilities between the subdivisions and stakeholders in the organization.

There are several questions regarding how tasks and responsibilities should be divided among stakeholders within the organization and beyond. For example: "Should maintenance be dealt with internally or externally, should the CE-markings be made internally or externally" (348i)? How these issues are resolved will have consequences for sub-divisions within the company and might entail radical changes to the established way of doing things. This is considered a problem for intelligent applications because there is no clear way these things should be handled within

It is common for sub-division within a larger organization to have different institutionalized ways of doing things and measuring progress. Talking about the various departments in any company, one of the industry stakeholders says, "sometimes they compete with each other at the expense of the common good of the company. There is much competition over funding. Who will be allowed to buy the new equipment" (348i)? Furthermore, management in the factories thinks that the departments preparing the processes and designing the construction have limited knowledge of what happens on the floor in production (973i)—and this indicates that an extensive transformation might entail problems in terms of collaborating and communicating relevant information between subdivisions within any large company.

5.3.3 The transition phase

While many of the blocking mechanisms to intelligent automation are articulated as specific issues, such as those discussed above and presented in **Table 4**, the transition phase is also understood as a blocking mechanism in itself. This relates to section 6.3.2 regarding organizational obstacles and 6.3.1 on technical obstacles. A manager at Volvo GTO explicitly states: that "we also have the threshold effect, I believe, the first projects to enter a factory will be very difficult because people have very high expectations, but the process is not mature and adapted" (942i). The same manager also says: "The first processes we automate, people will only see as a problem. 'Now that damn robot is giving us trouble again,' instead of seeing the benefits they provide" (942i). So, the transition phase becomes an obstacle in managing and coordinating organizational changes and integrating intelligent automation into the current processes.

There is also anxiety related to taking the leap of faith and trusting that they have correctly evaluated the technology readiness level of the technology in question. While the technology might have been tested, they must know that it will work over a long period (593i). When making significant changes, there is always a concern that they will complicate the overall process in the factory due to reasons that are difficult to predict. An industry stakeholder says: "If we get new technology in the factory, we must know that it doesn't create new problems or new risk for instability or disturbances in production" (348i). When making installations that are not perceived to be sufficiently good, these become bad experiences that can discourage further research or investments in such technologies. To overcome the threshold, it is argued that it is necessary to reach a critical mass of automation, so there is competence and knowledge about intelligent automation in the factory. A manager in Volvo GTO says: "When this threshold is passed, we will soon see many new possibilities for automation" (942i).

Automating the final assembly efficiently would require that all the departments in the company, from product design to aftermarket, are involved in this transition, making it challenging to coordinate this work and manage this transformation in the organization. Because of this, the transition itself is considered to be an obstacle. Starting significant scale changes without any clear good examples within the organization or outside makes it difficult to make such a change. It becomes a catch 22; you need a higher level of maturity of the technology to take the step to make investments. Still, it will be investments in the technology that will develop it. This further underlines the argument that intelligent technology cannot be understood as flexible or agile in the way that the manufacturers of cobots stress.

5.3.4 Cost of investments

The most significant obstacle for investments in cobots, ATRs, and further automation of the final assembly is the cost and the uncertainty about the payoff of investments (**Table 4**). This is an obstacle related to all other obstacles. While this is the case for all technology investments, it is more acute in the case of technology that is not yet thoroughly evaluated and that might not be compatible with existing technology or established ways of calculating costs and benefits; i.e., it might be more challenging to calculate benefits with increased safety, improved workplace ergonomics, or increased flexibility. The reluctance to invest in intelligent technologies is also motivated by the existing investments in machines and infrastructure. A manager at Volvo GTO says: "We cannot just get rid of [our current machines and factories] and start over if we suggested that to our shareholders, they would rather invest in new companies that don't have to take the conversion costs" (949i).

As argued in the previous section (6.2), investments in intelligent technology might have other benefits than streamlining the production—such as product branding or promoting the company as an attractive workplace. However, while such factors might motivate research projects and minor installations, they will not motivate large-scale investments. To make such investments, the industry has to be sure that the technology will work well and that they will be able to recoup the investments. A manager within Volvo GTO stresses that "in the early stages of technology development, we can afford to bring in equipment that does not pay for itself, but as soon as we say that 'this technology can fly by itself, then it is just like other equipment, then we must calculate on the profitability" (593i). Discursive benefits (e.g., marketing and branding) are also limited regarding technology upgrades on the production side. Another manager within Volvo GTO (973i) stresses that technology development on the production side is lagging because the technology is not directly visible in the final products:

> *Yes, I think that the management side does not think along those lines. There is no clear strategy for keeping up with technical developments [in the production]. You definitely have a strategy for this on the product side. […] But when we come up with an idea for a robot solution we want, we get the answer "Oh no… it will be too expensive.*

This manager says that the company lacks long-term strategies for technology upgrades in production because they are not immediately visible in the product and that technology upgrades in the final products are prioritized.

Furthermore, investments are not solely done based on calculated costs and benefits for technology upgrades; the industry stakeholders work within specific budgets and certain restraints that limit possible investments even if they are understood to provide future benefits. When making investments, the industry has to calculate future demands and preconditions for production, which are very hard to predict. Political decisions such as a possible outright ban on fossil fuel might demand a swift shift in production. The industry does not want to incur a too high base cost when they do not know what future production will look like. A manager in Volvo GTO argues: "we can become too investment-heavy, that is we incur a large base cost. And it will put the lid on if our base cost isn't competitive. We can end up in such a situation if you are not careful" (593i). Especially in times of uncertainty or economic recess, the budget for technology investments will decrease. The same manager says: "Right now, we are riding on an economic boom that has lasted for many years. And our suggestions for new investments are generally received positively. But shortly, things can be very different. And [in times of economic recession] the first thing you stop investing in, is this type of technology" (593i).

All these pros and cons with cobots and ATR:s boil down to the most critical factor in considering large-scale technology up-grades, whether or not they will be able to recoup the investments. As demonstrated in the previous chapter (6.3), there are significant similarities between how researchers and the industry talk about potential benefits of intelligent automation, similarities that can be explained through the close contacts and dialogue as well as the fact that they take part in similar public discourse and information from the manufacturers.

When it comes to perceived obstacles in implementing intelligent solutions, there are generally significant differences between industry and academic stakeholders where industry stakeholders are more damaging and perceive more obstacles. This difference can be explained from the point of view that the researchers evaluate technology in a laboratory environment or an experimental situation in the factory, while industry experts work in the factory with existing technology and machinery. The industry stakeholder must feel very confident that a solution works for a long time and that they will be able to recoup the costs of the investments. There are also significant differences between interviewed stakeholders within the industry. A general trend in the material is that researchers at the technical university and staff within the R&D department are more optimistic about introducing intelligent automation and human-robot collaboration than the middle management in charge of the everyday activity in the factories. This confirms the results in previous studies that there are differences between stakeholders depending on their position in society (e.g., Larsson et al. 2019; Parasuraman 2007; Reason 1997; Woods 1996). But in contrast to what is argued by Parasuraman et al. (2007), it is not the human factors engineers that are most reluctant to technology upgrades but the middle management responsible for the production at the factories.

Another significant perceived external obstacle, not discussed in this section, is the current regulation and safety standards that are understood by many of the informants to hinder the successful development of intelligent technology in the factories, especially as regarding the human-robot collaborative robot installations (this will be discussed in section 5.5).

5.4 External inducement mechanisms

In their investments in technology upgrades, Volvo GTO is influenced by developments and trends in the outside world. In deciding potential areas of use for automation, one manager (593i) stresses that other actors within the industry influence them:

> *[In the use of cobots] we have focused on elements where we have repetitive work [...] this is not our conclusion, but we have seen it from other actors who use such robots. They have used them for tightening screws to a considerable extent. We visited the Renaults factory in northern France, where they basically had an operator in every second station and a robot that operated a screwdriver in every other station.*

In other words, the use of cobots, ATRs, and intelligent automation and the perceived benefits of this type of solution are influenced by external actors. Interestingly, moves by competitors and external discursive factors seem to play an essential role in a business company's view on technology and its investments. However, the activities of competitors provide two crucial pieces of information. First, it can be assumed that the technology investments of competitors are based on thorough technology evaluations from the perspective of those competitors. Second, acting similarly to the rest of the industry is a way to ensure that regulations will not hinder their development as regulations and regulatory changes are generally done in dialogue with stakeholder interests.

While competitors' moves can motivate technology investments, it is also recognized that initiatives from competitors can create hype for a specific technology. One of the operators says: "[intelligent automation] might be important, but the interest is probably influenced by the fact that you look at what the competitors are doing and feel stressed and start believing that we are lagging. It's a bit, I'm not going to say fashion in it, but you think that the others are better off [in the technology development] and you feel stressed" (274i). In other words, his understanding is that the investments in intelligent technology are motivated by the competitors' initiatives. Several of the respondents recognize that a general technological development in society positively influences the view on the possibility to make further investments in intelligent technology in the factories: "Everything from the equipment you use at home, self-propelled lawn mowers and vacuum cleaners […] and everything you can connect to the internet, such as home alarms. It is obvious that this creates an interest and a drive among individuals […] [Y]ou see that it works in real life" (887i). One of the respondents within Volvo GTO understands the considerable interest in intelligent technology to be influenced by the German concept of industry 4.0 (488i), and say "we would never make these kinds of investments in technology development [involving cobots and ATRs] if it weren't for the ideas spread through the concept of Industry 4.0".

The influence of external factors is illustrated in **Figure 2** in the first column titled external inducement mechanisms stresses the importance of external factors as motivators for technological change. While external inducement mechanisms are recognized as influential on the company's views of technology, it is not a causal mechanism where external inducements directly influence technology investments. Instead, information from the outer world is critically assessed. If other companies adopt a technology, they will evaluate it in their production, as demonstrated by the comparison between the French factory and the Swedish factory in the example above.

While the responsiveness to technology development and competitors' initiatives within the automotive industry might encourage the development of intelligent automation, other factors might point towards another direction. There are also conflicting inducement mechanisms from the outside world. A manager says: "But if you look around, other engine manufacturers [in the automotive industry] invest quite heavily in conventional automation of the same type that we use today. And that can also point us toward how we should invest in the future" (593v10). So, while outside discourse and input from the other world can work as catalysts, additional information and conflicting trends work in the opposite direction.

5.5 Views on safety and regulation

5.5.1 Views on the current regulation of intelligent automation

The safety of intelligent automation, cobots, and ATRs is evaluated using the same principles as any automation or technology within the industry. Standard regulations within the EU regulate the manufacturing and use of industrial machines, robots, and equipment. The Machinery Directive (2006/42/EC) is the guiding document for safety evaluations. Like other technical equipment, the safety evaluation is guided by the EU Machinery Directive (2006/42/ec) and other ISO standards that have been developed to meet the requirement of the machine directive (such as **ISO**/TS 15066:2016). Based on these documents, all machines and assembly lines must be evaluated and labeled with a CE label to ensure that they meet applicable safety standards. While assessed by the same standards as any machinery, there are concerns regarding the installation of intelligent automation in the instances it is to be used in proximity to human operators. Traditional automation in the automotive industry uses heavy robots with large force and operates at high speed. According to the Machinery Directive, such robots need to be fenced to protect humans from potential harm. Smaller collaborative robots use less force and are generally CE-marked by the manufacturer to be safe for use in production together with humans. Although the robot is CE-marked by the manufacturer, it also needs to be CE-marked in the specific setting where it will be used in the factory (a line of machines). While the co-bot might be CE-labeled, the installation in the factory must be CE-marked because it will be equipped with new tools and operating with other machinery with a joint control system.[5] The safety evaluation becomes more difficult if small robots, unlike traditional industrial robots, work in the same physical space as humans.[6]

There are some concerns over safety regarding introducing intelligent automation in the factories, and all interviewed stakeholders consider it crucial to address this issue in both research and during installations in the factories. However, in general, the intelligent applications discussed within the scope of this report are understood as safe by involved actors. Rather than being a safety issue, intelligent automation is considered to improve safety in the factory. One manager at a factory in Volvo GTO says: "I do not think there is a problem with safety concerning the programming of the [collaborative] robots. […] [T]here are many redundant safety systems. So, I do not see [safety] as an obstacle" (931i). Another manager stresses that ATRs are safer than the trucks and forklifts operated by humans (931i; 154i). "The [ATR] that we are about to introduce means that humans will not have to walk in the truck aisle, which is a large safety benefit" (931i). So, both the collaborative robots and the ATRs are generally seen as safer than the equipment used today (876r).

While generally considered safe, there are several concerns regarding current regulation and how to make intelligent automation work within current regulation and safety standards (593i). The regulation of intelligent automation and collaborative robots is much discussed, especially within the industry and the government agency responsible for the work environ-

5 The CE certification for a machine line consists of two or more assembled machines. If two or more machines are combined to form a group that functions as a unit, a declaration of conformity must be issued for the whole group of devices, and a CE certification for the entire station is required. This is usually the case even if the included machines are already CE certificated by the Swedish Work Environment Authority's regulations on machines, AFS 2008: 3. The entire machine line must be CE-certified if it has a common control system.

6 For further information on regulation see homepage of the Swedish Work Environment Authority (www.av.se), and the Machinery Directive (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32006L0042)

ment, but also to some extent among the researchers. As discussed, all machines and machine lines have to be CE-labeled—meaning that the manufacturer signs the Declaration of Conformity after making a thorough risk assessment and documentation. Making this risk assessment for intelligent automation and collaborative robots is in one regard very similar to the evaluation of any other technology. An operator at Volvo GTO says: "We have a protocol for risk assessment […], by which we assess all work tasks, there is really no difference [with intelligent automation] compared to other tools and robots that we install" (274i).

Cobots are, in most cases, CE-marked by the manufacturer. When applied in a new setting in the factory, the safety has to be re-evaluated, and the robot CE-marked in the new environment, and someone must be listed as the "manufacturer" of the installation. "It does not matter if the co-bot has [built-in safety systems], you still have to do a risk assessment of the overall system" (869i). A manager explains: "We can buy a cobot today, which is CE marked, but if we equip it with a knife, it is no longer safe" (949i). Furthermore, risk assessments become more complex when robots become more intelligent, re-plan routes according to outer stimuli, and optimize their actions due to previous experiences. In such cases, safety evaluations have to be done through data simulations and statistical analysis (876r). A manager at Volvo GTO stresses that: "[Regulation of intelligent automation] is a huge challenge. The smarter they get, the more difficult it becomes. Just to CE-mark something where you do not have full control over what it does, we expect it to make its own decisions. Then everything becomes very complicated. Who takes the responsibility" (949i)?

Nearly every industry stakeholder considered current regulation not to be well adjusted to cobots and intelligent automation in the factory. Regulation is considered too strict and an obstacle towards introducing cobots and intelligent automation in the factories (**Table 4**). What is more, the regulations do not concur with what is viewed as an acceptable risk in the factories. A manager in Volvo GTO says: "Unfortunately, the standard is not adapted to what we as humans may accept as a risk" (869i). An example of this is discussed by one of the other managers (869i) at Volvo GTO:

> *There is a standard called TS15066 which is not mandatory but rather a technical description. […] And there is a wording [in this standard] that is very difficult to follow, and that is that you must not allow any force from the robot in the area of the head or above the neck of the operator. It indirectly means you need to have an employee who cannot bend his head because [if they] bend down to pick up something from the floor, they might enter the robot's work area.*

The industry stakeholders understand the strict regulations to be counterproductive as the collaborative or intelligent solutions are considered safer than the installations they would replace. One manager in Volvo GTO (942i) says:

> *I feel that sometimes safety is taken a step too far. An example: what is the probability that someone comes running at full speed into a cell and runs straight at a robot? It can happen—so we have to consider it in the safety evaluation. But to get efficiency and flexibility in simpler automated installations, you must rely on a specific intelligence from those who work next to the robot. [...] You shouldn't hurt anyone, but at the same time, you cannot add on too much safety because then it will be too complex and too expensive and too slow.*

In trying to highlight the perceived inaccuracy of the regulation concerning intelligent automation, some respondents compare collaborative robots and other situations to show that the regulation is not based on "common sense" (488i). A manager says: "a human being can also act unpredictably. But it is still allowed to work next to another human" (942i). Another manager compares robots to farm animals and stresses that it is acceptable to work with cattle, although they also have a "mind of their own" (488i). Yet another manager says: "if I hit my colleague with my tool when I turn around, it's okay, but if the cobot does the same thing, then it's a bit like when a dog bites someone, then it should be put down, so it's like … then we will probably see a witch hunt" (949i). With these above statements, the respondents want to underscore that the risk evaluation of intelligent automation is not in proportion to a common-sense understanding of acceptable risk.

In most cases, the concern regarding current regulation is not that it is impossible to install intelligent applications; instead, the process for CE-labeling and the safety directives requires redundant safety systems that make the solutions slow and inefficient.

[T] the big challenge will be to resolve the safety issues reasonably cost-effectively; you can always build any number of safety systems and make them safe. But then you get a very rigid and expensive installation. […] We also have to solve the safety issues so that the robot installation becomes efficient. You can always resolve the safety concerns by making the robot go very slowly, but then the robot will be useless. (942i)

So, in the view of the industry stakeholder, the regulatory requirements make cobots too slow, and it makes it difficult to find practical applications for such robots. The requirement to make new CE-labeling or update the documentation for every new application in the factory adds to the perceived difficulty in achieving desired flexibility. So, while manufacturers of collaborative robots and automated guided carts consider these to facilitate flexible automated solutions, the industry stakeholders say they would most likely have to make new risk evaluations and update the documentation for the CE-marking with any future changes to the system. Thus, the regulatory obstacles are thus understood to be obstacles for flexible use of intelligent technology (593i).

While also possibly behaving unpredictably by updating their route, transport robots are considered easier to introduce with current regulation compared to cobots (e.g., 869i). While cobots use force sensors to make them stop if you come into physical contact with them, transport robots utilize lasers. They can therefore stop without any physical contact with a human. But most importantly, they will operate mainly between workstations in aisles designated for traffic rather than in the workstations. The transport aisles are considered easier to automate because they are meant for machines to operate within, and the safety is, therefore, easier to guarantee (compared to having a robot in an assembly cell).

Most interviewed researchers share much of the industry's views on safety and regulation—i.e., that it is not well adjusted to intelligent automation, except one researcher who did not recognize regulation as a problem. However, the researchers say that their knowledge of regulation is limited and mainly derived from conversations with the industry. The regulatory concerns are not as pressing for researchers; they can make their experiments without necessarily being concerned with industry-related regulation. The researchers interviewed for this study are very much involved in making the applications safe for human operators to use but approach this from a technical point of view. They see it as their task to develop technical solutions and leave the regulation to other societal actors. However, some researchers also express an interest in increasing their knowledge of regulation.

In the interviews, the industry experts and the researchers were asked if intelligent technology (AI-powered control systems or robots that change route interacting with the surrounding area possibly utilizing self-learning AI-algorithms) shift the division of responsibilities and liability in case of an accident. The standard reply is that responsibilities and liability are regulated through standardized legal contracts. A manager from Volvo GTO says: "In every purchase we make, we have standard contracts, where it is stipulated who is responsible for what" (154i). From such a perspective, liability issues remain the same as with non-autonomous machines, which means there is no essential difference between an autonomous machine that acts unpredictable from a malfunctioning electrical screwdriver. However, some respondents reason differently and claim that this issue might have to be reconsidered in an age of intelligent machines and argue that intelligent automation requires a re-conceptualization or a re-thinking of how the responsibilities should be divided among the actors in society.

5.5.2 The invisible safety/ danger

When it comes to cobots, ATRs, and other machinery operating in proximity to humans', safety will to some extent depend on the programming of the control system. Thus, the problem of regulation of intelligent automation relates to the invisible safety in software or control systems. While this is a problem with all control systems operating robots, it is especially relevant when the robots operate in the same physical space as humans. If driven by AI-algorithms that are self-reinforcing and the devices automatically change the code of the software, it will further increase the difficulties associated with evaluating safety. So, while the functionality and possible malfunction of automation is very much dependent on the programming of the control system—this kind of safety is very much invisible. The software code is difficult to interpret in relation to a specific incident. Furthermore, the code is often not accessible because the programmer of the code considers it to be a business secret (205o).

According to one of the respondents within Volvo GTO the invisibility of the safety makes the risk evaluation for the CE-marking more difficult, "in addition, you must make a CE-marking, and you must prove that your programming of this particular robot has succeeded, it is not visible, but it is in the software" (154i). The same respondent elaborates this further:

> *And since there are no fences, it is the software, this invisible thing, that controls safety. On a regular robot, you have a fence; it is physical, you can see it, and you can say 'there it is' if you open the door to the automation cell, the robots will shut down, and so on. In the case of intelligent robots, you have to look at the code, but it doesn't say much; you almost have to try it out […] Will the robot stops in a situation where it can potentially cause harm to operators?*

It isn't easy to prove that the programming of a specific robot is successful (154i), and the interviewed researchers say that an essential part of their safety evaluation of such devices is to run tests to verify that they will function as predicted with a certain probability (876r).

The "invisibility" of safety is also understood to be a problem in evaluating safety for government authorities. One of the Swedish Work Environment Authority respondents stressed the difficulty of assessing the control system at an inspection. Although the machine line's control system should be evaluated according to regulation (Arbetsmiljöverket 2020), the representative says that the control system is a blind spot for them. He claims that it is difficult to interpret the code and that the manufacturer does not want to provide them with the code because it is considered a trade secret (205o). He says:

> *There is a weak link in the oversight process - identifying who is responsible for the software. We can assess all physical*

> *components and see if it has a safety certificate. But we cannot access the programming and updates of programs, logs, data, and journal of updates.*

Another respondent confirms this problem: one of the researchers says that "a malfunction in the control system will probably be understood as a problem with a sensor or some other hardware in the robot" (876r). Researchers confirm that the system's invisibility is a problem for safety; the safety of intelligent automation depends on the coding of the control system (876r) and simulations of probabilities of malfunction.

5.5.3 Suggestion for future regulation

Nearly all respondents within academia and the industry stress that the regulation of machines and robots is not adequately adjusted to intelligent automation. Some emphasize the lack of experience in making such safety evaluations. Experts within the industry argue that the lack of binding case law from either the EU court of Justice or/and from national courts contributes to the difficulty in pursuing risk analyses for intelligent automation based on the EU directive (348i). One of the respondents expressed the view that Swedish companies may be too anxious and eager to do the right thing, compared to companies within other countries in the European Union (348i), and argue that it probably is possible to make less strict interpretations of the Machinery Directive while doing risk assessments to accommodate needs for the future of an intelligent factory. From this point of view, interpretations of the regulation and risk assessments will get easier over time and could be regulated within the current regulatory framework with some minor adjustments (593i; 378r).

While some of the respondents understand the current regulatory paradigm to be sufficient to deal with intelligent automation, others recognize the need for a radical reconceptualization and fundamental changes of existing regulation. Among those who prescribe large changes in regulation, there are no ready-made solutions for how such new regulation should be made. However, there are suggestions that risk assessment should not only build on physical barriers but rather on education (488i), communication, and trust (488i). From such a perspective, the respondents also understand it as necessary to make a certain degree of risk acceptable: "if the operators get an education in these systems, they will consider these risks acceptable" (869i). Some degree of risk acceptance is generally considered necessary to facilitate what they believe to be safer solutions compared to existing machinery (488i). Researchers suggest that it should be possible to make the software or control system part of the safety evaluation. This might, however, become a problem within the current paradigm of regulation and safety evaluation that is very much based on visible safety and hardware. There are also suggestions that intelligent automation should be regulated as animate objects rather than machines, such as viewing and regulating intelligent robots in the same way as farm animals (876r). They emphasize that humans are allowed to work with farm animals, although they have a behavior that cannot be fully predicted.

Another suggestion presented by some of the researchers (295r, 876r) is that the human operator, in some cases, should allow the robot to operate at a higher speed and to use more force when the robot needs it, something they term "deliberative automation" (876r). This deliberation requires that the robots and humans communicate and interact intuitively and let them change the safety measures while they are operating. A similar idea is also discussed by one of the managers at Volvo GTO: "We are looking at solutions where a collaborative robot senses when people are nearby and adapts to it, but it can also operate at high speeds and use enough force to handle the weights we have in our products, it is an interesting solution to be able to operate a robot at high speed, but when humans approach it slows down, and you can work together" (949i).

From the perspective of the Swedish Work Environment Authority, they recognize a need for possible regulatory changes but stress that the development of rules and standards must take time as they are based on negotiations and agreements between many different parties. A suggestion for making the work easier with regard to intelligent automation from the perspective of the Swedish Work Environment Authority is a larger degree of coordination between topics such as "cyber security, digitalization, programming responsibility, and clarification on what the manufacturer's responsibility is and what the user's responsibility is "to facilitate the work at different authorities" (205o).

5.6 Distribution of knowledge and responsibilities in the intelligent factory

5.6.1 Needed knowledge and skills in the age of intelligent automation

To what extent is a gradual introduction of intelligent automation understood to require new knowledge and skills among the employees in the factory? While intelligent applications generally are technically advanced and will be increasingly more advanced with future development, some respondents within the industry stress that it should not require any specific new skills or education to work as an operator with these devices. Many of the respondents stress that the technology should be intuitive and easy to operate and that the robots should be self-learning (949i). In short, there is an understanding that the construction of workstations should be simple and shouldn't require a lengthy education to operate (973i). But just as with all machines, it is understood to require some training: "Yes, of course, they need training if they are to operate a machine instead of [manually] assembling a console so that they may need more technical training. At the same time, I believe that an internal education for the station where you will work will suffice" (931i).

Nearly every respondent stressed that personal experience and embodied knowledge is essential in working with collaborative and autonomous robots. A general understanding is that habituation is more important than formal education in working together with intelligent machines. The respondents stress that when introducing such applications, people must get hands-on experience with these devices at an early stage. A manager at Volvo GTO also says that home devices such as robot vacuum cleaners, lawnmowers, and other self-propelled machines in everyday life will gradually make people more at ease in working with such devices in the factory.

The required knowledge level is understood to vary with the configuration of the specific workstation(s). The level of knowledge is dependent on what kind of intelligent automation is used, and what the responsibility of the operator will be. One of the managers (154i) says that the level of knowledge about robots among the operators is dependent on which station they are working in; operators working in the mainline don't need to know much about robots, while the operators in the pre-assembly should be able to have more control over their work and to make adjustments to the program of the automation system (154i). The required knowledge level is also understood to vary with the degree of collaboration with the robot and how you "have designed the solution" (973i). Another manager (488i) says:

> *If you find yourself in a close collaborative situation [with a robot] where you lift things together, I think it is essential that you go a little deeper and explain how the robot gets its input signals and how it functions. For example, they need to know how the robot will act if it malfunctions. I think this is important for the individuals too, on the one hand, to feel safe with it, and on the other hand, be able to utilize the robots according to their full strengths and weaknesses.*

So, while habituation and experience generally are considered more important than knowledge, some intelligent installations are understood to require a more in-depth understanding of the robots and the way they function.

5.6.2 The division of roles and responsibilities in the intelligent factory

As discussed in section 6.3.2 on organizational obstacles, there are concerns over how to divide roles and responsibilities in the organization given an increased level of intelligent automation in the factories. The division of roles and responsibilities is intimately linked to the level of knowledge required by the operators, if, for example, the operators should be able to reprogram the robot and to be responsible for maintenance, it will challenge existing roles and divide responsibilities among sub-organizations within the company (942i). Some of the managers see a future development where operators will do some of the programming of the robots (949i)—especially in the work stations in the sub-flows to the main assembly line. Such a development would require more in-depth knowledge about the limitations of the robots (949i). But if maintenance and support and programming of the robot/control system is to be handled by the maintenance department or by an external sub-contractor, the roles, and division of responsibilities would remain largely intact.

Some suggest that operators should be trained to deal with simple maintenance of the robots and simple troubleshooting, but experts should do significant repairs and re-programing. How to organize roles and responsibilities in intelligent automation is not straightforward. One of the industry stakeholders outside Volvo GTO emphasizes that defining roles and responsibilities in an age of intelligent machines will be a significant challenge, for example, deciding who should program the robot and who should make updates for new products to manufacture (348i). A manager in a factory who has worked as an operator early in their career emphasizes the drawbacks of involving operators in programming the robots. The manager stresses that it is a risk to let people who are not sufficiently skilled work with the robots and add that it would be challenging to determine what settings they should be allowed to change.

> *I do not know to what extent operators should be able to make changes in the work process. […] There is a risk that if there are many who are inside and tinkering with a system, most of whom have no more than a basic understanding of it, then, in the end, you create problems. So, it is tough to decide on the role and responsibilities of the staff—what is a job for an integrator, what is a job for a local technician, what is a maintenance job, and what is a job for an operator. […] I believe that the division of responsibilities associated with the different roles will be pretty tricky in the beginning. (942i)*

It is recognized that it can create problems in production if there are no clear-cut distinctions of roles and responsibilities between operators and technical support. While further educating the operators and giving them increased responsibility can be understood as a way of empowering them and giving the operators a sense of control over their situation, it can also be understood as a way of delegating responsibilities without delegating influence over their situation.

It is also recognized that an increased responsibility can lead to stress among operators feeling that they are responsible for any malfunction of the automation system. The manager says: "So personally if I had been an operator, I would not have wanted to mess with the programming of robots. Rather, it would have felt safe if someone with expert knowledge had the responsibility for this" (931i). All and all, how the responsibility is divided is not so much a question of the nature of intelligent technology but an organizational question of how to demarcate the roles and responsibilities of different categories of employees at the factory. A manager says, "The question is what path you choose, should only staff with a specific skill set be allowed to alter the programming, should the operator be allowed to make these changes, or who should make them. It is important to have clear guidelines about this" (931i). Differences in views on how to divide responsibilities are not so much a question of the nature of technology but how to divide roles and responsibilities in the organization in the best possible way. However, as stressed by some respondents, utilizing intelligent automation in the most efficient way might require a reorganization of responsibilities in the factory so that operators are assigned new roles. All and all, introducing intelligent automation might pose challenges to the existing organizational structure and the established division of roles and responsibilities in the factories, but in what way, and to what extent, is difficult to predict.

An issue related to knowledge and division of responsibility in the intelligent factory is how to divide the work between humans and robots. It is considered essential to do this so that the strengths of humans and robots respectively are utilized. In the interviews with industry and researcher stakeholders, it is stressed that human qualities are their flexibility and dexterity—qualities that make it easy for humans to compensate for product variation, differences in indexed stops in the assembly line, as well as slight differences in the materials used in the assembly station. Robots, on the other hand, are understood to be suitable for repetitive work with high speed and accuracy. Robots are understood to be better at performing repetitive actions, while humans are understood to be easily distracted (869i). A manager within Volvo GTO says, "We have some jobs that are difficult for a human to repeat, where a robot is more stable in doing the same thing repeatedly" (942i). A robot, for example, would not forget a step in the assembly process, given that it is provided with correct information. Things that are considered difficult to use the robot for are entering screws, localizing objects to work with, unpacking materials before assembly, attaching the cables along the chassis frames, to mention a few examples. Although the capabilities of humans and machines respectively are understood to be easily defined (as above), dividing work between humans and robots is considered challenging to organize in a good way (see **Table 1**).

Many of the informants are also talking about utilizing the robot to educate and train the human operators (876r). The respondents from within the industry but especially from academia recognize the possibility of making the robot educate the operator on its essential functions and providing instructions for a specific task at hand. For example, it can communicate to the operator that it needs to change a spare part and instruct the operator on how to change it (348i). There are also many ways humans and robots can reinforce each other's strengths. The robot can provide instructions and education for the human operator and supervise part of the work to improve the quality of the work performed by the human. And by having a human operator next to the robot, the humans can control and correct possible mistakes made by the robot due to errors in correctly identifying a product.

5.7 Human-robot relations in the intelligent factory

5.7.1 Building relations between humans and machines

The respondents in the study were also asked about challenges related to creating suitable interfaces or good ways to communicate between humans and automation systems, given a potential increase in human-robot collaboration. There is a concern among the respondents about how to construct good interfaces and build trust between humans and robots working in close collaboration, a matter discussed by both industry stakeholders and researchers. There is a general understanding that humans will need time to adjust to working closely with robots. The respondents highlighted several reasons making it difficult for humans to work in close collaboration with robots (931i). One is the lack of knowledge of how to control or manipulate the robot; a manager says that "an ordinary person has more knowledge about how to influence a human [compared to a robot]" (931i). People are used to communicating with humans, and humans can communicate their actions and intentions easily through their voice and body language. Another stressed reason for the difficulties in human-robot communication and trust is that operators might become irritated or scared when a robot operates in a way that you cannot fully predict (949i), and they can become frustrated when they need to wait for a robot to finalize a task.

An important aspect of this initial reluctance for humans to work in close collaboration with robots is the invisibility of the safety system (as discussed in section 6.5) and the difficulties involved in relating to the robot's behavior. The operator cannot see the safety mechanism the same way they would see a fence or any other physical safety measure but must rely on invisible safety measures (section 6.5.2). It is recognized that intelligent automation requires trust and confidence in the robots to a larger extent than working with traditional automation. Trust is an essential aspect of working with any machinery, especially when working with machines that re-plan their routes and adjust to the environment and the action of humans. In this regard, there is not so much difference if the devices act somewhat autonomously using AI algorithms or if they are only perceived as acting autonomously in responding to many different inputs by the humans working beside them. According to several of the interviewed stakeholders, education is an integral part of establishing trust; a manager says: "you […] need some education—that is my opinion. If you understand what kind of animal you are working with, then you also understand its faults and shortcomings and can adapt your actions accordingly" (488i). One of the interviewed researchers (722r) says that the robots could educate operators for a specific work task. For example, the robot could perform a task to be repeated by the human operators, and cameras could be used to analyze if the operator has executed the operation correctly (722r). As discussed in the section on knowledge (6.6.1), many understand experience as more important than education in establishing trust in automation. Establishing trust from the respondents' perspective requires hands-on training so that the operators get used to working with the machine. This is generally considered more important than showing PowerPoint slides and theoretically educating people on how the devices are programmed (942i). The quote below, from a manager within Volvo GTO (942i), is illuminating for how many of the industry stakeholders think:

> *An operator [working with an intelligent machine] needs to understand what the system does and what the system wants to do. I do not think it is important for the operator to understand how the automation arrives at this conclusion. If you work with a human, you do not focus on what he thinks but on what he does.*

It is also recognized that getting used to the equipment and gaining embodied knowledge of the machines takes time. "Now we have one robot here, and as you start to trust them, that they will function, you gradually change your perception and increase the acceptance, it will be something normal eventually, but everything takes time" (274i). It is furthermore recognized that close contact with robots in everyday life will translate into increased trust in intelligent robots, e.g., communicating with Alexa or Google Home, operating the robot lawnmower or vacuum cleaner; all these things are understood to gradually make people more prone to work together with robots in a work environment.

Many of the respondents stressed that humans create relations with machines and understand the process of establishing trust in robots to have similarities with establishing relations among humans. One of the experts interviewed from Volvo recalls a situation where he encountered a driverless car at a zebra crossing. He looked at the vehicle to evaluate if it would stop or not. He first looked through the window to where the driver should have sat. Then he looked at the car's spotlights because it was the closest thing to being the eyes of the vehicle, to try to get some kind of contact. He was surprised to see that he started reflecting over the questions "who are you," "what do you want," "can I trust you" (488i). This same manager at Volvo GTO understands the relations between operator and robot to be the key to developing a successful communication between humans and machines. Because of these human-like connections with the robot, the importance of using human contact and human behavior for designing the interface between humans and robots in the factory is continuously stressed in the interviews. This will be discussed in the next section on designing suitable interfaces.

5.7.2 Designing a good interface

To make operators trust and feel comfortable in working with intelligent automation, it is considered of essence to plan the collaboration between humans and robots well and design the interfaces (i.e., the way humans and computers interact) in a good way. This includes deciding what information should be communicated between humans and robots and how this information should be communicated. Designing suitable interfaces is especially important when working with robots that will not execute operations in a fixed sequence. A manager at Volvo GTO (949i) says:

> *These new systems will not always repeat the same cycle. […] These new machines will sometimes do things that they have never done before, and how do you [as an operator] know if it is right or wrong? Should you press the emergency stop, or should you let it continue? So then, there is the question, 'how do you get this communication between man and machine to work'?*

A good interface is understood to help establish trust between the human and the machine. A crucial part of this is making robot behavior comprehensible and predictable to the human operator. "It is difficult [for humans] to understand the logic [of the intelligent robot], why it behaves the way it does, you do not know why it suddenly turns right and makes a sharp turn. So, when the robot behaves illogically, you quickly notice that people become annoyed" (949i).

Given that humans are to work in close collaboration with robots, the interface and the communication between humans and robots must compensate for the continuous dialogue and silent communication of two humans working together. A manager at Volvo GTO says: "When humans are working with other humans, they can interact with small signals, but if you do not understand the robot, it can be very stressful with the ambiguity in what the robot does" (949i). Another manager (942i) talks in some more detail about human-robot interaction:

> *When you work with another person, you interact in many different ways. You look at each other, you see what the other person is doing, you can shout, you can warn each other with a simple sound, and above all, it is pretty easy to see when the other person wants me to do something. With an automated process, these things become a challenge. At least if you want a close connection between the operator and the automation.*

As seen by this quote above, this manager explicitly states that the challenges of designing robot-human-communication need to compensate for the communication between humans to work smoothly.
An essential thing for improving human-robot relations is to make the robot's actions predictable and intelligible to the human, for example, by avoiding sudden movement that might scare an operator. It is considered beneficial to have some way to show the human what the robot is doing and what it is planning to do.

> *The robot must know where the human operator is to be able to work, to fulfill its function. In the same way, the operators must know what the robot is about to do next and where it is in the sequence of completing a work task without being overloaded by information. Only helpful information [should be communicated] (295i).*

Both the informants from academia and industry recognize the importance of making the movements and actions of the robots predictable so that the operator is not surprised by any sudden or unexpected movement because this can scare the operator or make the operator think that the robot is malfunctioning. A manager asks rhetorically: "A person becomes aware of another person seeing him, but how can you become confident that a robot has noticed you" (949i). It is considered necessary for the human operator to understand what the robot is doing through some kind of interface where the human can see what sequence the robot is in and what comes next (931i). This is sometimes referred to as "projected trajectories" or visual motion planning in the research literature (e.g., Zhang & Ostrowski 2002). It is a way of making the human aware of the future action of the robot. This can be done through virtual eyes, as is the case with the Sawyer Robot from Rethink Robotics (Rethink Robotics 2022), by using text messages on a screen, projection mapping using a projector or a laser that projects the planned trajectory of the robot, or through augmented reality glasses to take a few examples (378r; 722r). In addition, humans also have to communicate what they are doing to the robot, for example, informing the robot that they have completed a specific task and want the robot to proceed (942i; 722r).

Another thing considered necessary is making interfaces between robots and operators easy to comprehend because of the short station times (154i). A manager says: "it should be very, very easy to control and stop the process. There should be no doubts about how to get the robot started, or how to get it to perform its assignment [...] that is the most important thing" (154i). Along this line of reasoning, another manager (931i) considered it advantageous if the operator could choose whether they need the information from the automation system or not.

> *I believe it is good if the operators can choose whether they want to take in information from the robot. If you are a new operator, you may gain a sense of security in seeing when the robot does what. More experienced operators may have a better idea of what the robot is doing and may not need to take in information all the time. [...] So I think it is good if the operator chooses whether it wants to take part in the information, there should rather be too much information available than too little.*

Another manager makes the same point about letting the operators choose what information they need for their work. The manager argues that the operator can be more relaxed when they don't continuously have to take in information from the robot. Aligned with this argument, a researcher stresses that it is essential that only useful information is communicated (295r). This is in line with a general finding in engineering studies that interfaces should be designed to avoid cognitive overload (e.g., Morton et al. 2019; Ramakrishnan 2021). Another manager at Volvo GTO stresses that one has to be careful in introducing collaborative robots and ATRs as they might increase the complexity and thus also the stress for the operator (488i). So, while robots working with human operators might relieve the workers of some heavy or repetitive work tasks, it is also recognized that they might increase stress.

Devices like touchpads, smartwatches, and light signals are mentioned as examples of suitable interfaces for the communication between operators and automation (491i; 295r). Augmented reality applications are also discussed as possible solutions for designing an interface between operators and robots (348i; 722r). Many also stress the benefits of 'human-like' communication such as voice commands, hand gestures, eye contact, and body language to organize the communication between humans and robots (942i). In stressing the perceived ideal for human-robot communication, one manager at Volvo GTO's R&D department stated that "[t]he vision is that this communication should take place in the same spectrum as we humans communicate, i.e., verbally and with gestures. But also touch and feel so you can take hold of a robot and move it in any direction. Humans and robots should communicate the same way as humans" (488i). While voice communication is talked about as a viable solution by some respondents, most of them stress that there is too much noise in the factories, making it difficult to use such an interface. Furthermore, they do not want to add to noise pollution (942i).

Human-like communication has the benefit of being intuitive for humans to understand. One of the interviewed researchers says: "It has been demonstrated that if you make automation more similar to humans, which is usually referred to as embodied automation, it is easier for operators to adopt automation" (378r). Some respondents recognize that humans today have different ways of communicating, differences that are both individual and cultural. In response to this, one of the managers in Volvo GTO stresses that the way the robot communicates will be adjusted to one person—a standard person. This is because it is easier for humans to learn how to communicate with the robot than making a robot understand different ways of human communication and adapt to individual and cultural differences. Hence, while such interfaces make communication more human, they can also rectify specific human behavior and make operators adjust to a certain way to behave. This example illustrates how humans are influenced by and co-evolve with technology (see theory section).

It is recognized in the previous research that a significant challenge for introducing human-robot collaboration in production is how to design a good interface. Villani et al. (2008, 249–50) write:

> *…to take full advantage of human skills, intuitive user interfaces must be appropriately designed so that human operators can easily interact with the robot. This requires that, on the one hand, providing inputs to the robot and programming should be intuitive for the worker so that they are less concerned with how to communicate and is free to concentrate on the tasks and goals at hand.*

The result in this section goes hand in hand with such a perspective. Furthermore, it is recognized by the industry stakeholder (both in management and among operators) that interfaces and communication should be as simple as possible, which is aligned with the research literature stressing the importance of avoiding cognitive overload (c.f., Morton et al. 2019; Ramakrishnan 2021).

While making the collaboration between humans and robots work well is a technical and practical question, designing suitable interfaces and building trust between humans and machines is a philosophical question related to cognitive science and ultimately to the question of human nature. In what ways do humans understand communication? How do humans relate to non-animated objects? How do we make humans trust non-human entities? To what extent can human behavior be manipulated, and to what extent must machine be adjusted to human capacity and tendencies. This discussion opens up for bigger questions in need of further research and public debate. The following section will address the operators' perspective and how management within the factories and researchers view the operator's perspective in the introduction of intelligent automation.

5.8 The operators

Wile technology development is done by researchers at the universities and the management and the R&D department of the factories, the machines and robots will be operated by workers in the factories. Therefore, understanding the operators' views and perspectives is vital to understanding the possibilities and obstacles of introducing intelligent automation and collaborative robots in production. As stated in the method section, three operators were interviewed for this report. Two of them had the experience of working with a newly installed collaborative robot. In addition to these interviews with operators, the researchers and the management within Volvo were also asked about their perspective on the operators' views on introducing advanced automation in the factories.

The three operators interviewed for this study were all favorable to technical development. They understood the development of automation of the final assembly to be of the essence for keeping a competitive production in Sweden. They have faith that introducing (intelligent) automation will reduce heavy, repetitive, and tedious work tasks rather than replacing human operators in the factory. One operator stressed that the "[r]epetative work isn't good for the psychic or the body" (491i). All the operators understand ergonomic improvement to be the most important motivation for introducing intelligent automation in the production; they also say that they or people they know have body damages and pain in knees, backs, and shoulders due to heavy and repetitive work (491i; 635i; 274i). They also stress that improved ergonomics would increase quality and efficiency.

There is also a shared understanding among the operators that intelligent automation of final assembly could make the factories in Sweden more competitive in relation to other factories, especially in low- or middle-income countries. One operator says: "It is important that the factory remain here for the sake of the local community […] and if we show that we can produce this and this quantity, with a good quality, maybe the management will keep the factory running" (491i). All the interviewed operators understand technological development and intelligent automation to help facilitate this. There is also some degree of tolerance for staff reduction due to automation if that helps keep the factory running locally

(274i). This reduction of staff, one of the respondents said, can be handled by not recruiting new staff when operators retire or quit their job for any other reason and do not necessarily have to lead to layoffs. The operators interviewed seem secure in their position. They do not see automation as a direct threat to their work in final assembly and have a shared perception that most of the work done in the factory will continue to require human operators (635i, 274i). Although none of the operators interviewed expressed any concerns regarding the future of the labor market for their position due to automation, they recognized that some operators have such concerns.

Two of the operators had experience working with collaborative robotic applications and expressed a shared understanding that it made their job easier and felt safe to work with (491i; 635i). However, one operator (274i) underlines that while the robot might make the job easier, it might increase the work burden if it is not working correctly:

> *If you install a robot at a workstation, the operators' workload is balanced after the robot's capacity; if it stops operating, someone has to do the job. And it often takes longer and creates more stress. I have heard people talking about the robot we have here, they say that it is good as long as it is operating, but when it is not functioning, they are overwhelmed by the workload.*

This quote is an example of how bad experiences can negatively influence the will of industry stakeholders to make further investments in technology.

The operators stress that the critical part of introducing intelligent technology is proper demonstrations of the equipment and training and being included in the process of introducing the new technology. Asked about the extent to which they want to know how the machine works, one of the respondents replied that he only wanted to know the basic details relevant to operating the machine. However, they all also express that they would be willing to learn new things and change their work tasks if required. From the perspective of the factory workers, it is preferable that they can get training in dealing with such new machines—so their jobs are not taken over by subcontractors (274i). They envision future technological changes as part of development but stress the difficulties in making any exact predicaments about the extent of any future changes (635i). Technical development is also understood to improve ergonomics and the working conditions in the factory continuously.

There are different views on potential generational differences in the ability to adjust to new technology. Some say that the younger staff learn more quickly, have more extensive experience with computers and other digital tools, and have a more positive attitude to technology and change (491i; 635i). On the contrary, one of the operators says that he thinks the generational gap is exaggerated "I believe that the differences are on an individual level. Some people love change while others hate it. It is easy to say that older operators are against technological change—but I do not believe that" (274i). He says that while younger operators may be used to computers and touch screens, they are less skilled. One of the operators expressed concern about the social aspect of working together with robots instead of humans. "Of course, if you have seven robots that you work with, and no one to talk to, it may become a dull work environment, and in that way, it can be a disadvantage" (274i). A manager who previously worked as an operator stated, "It might be because I am an emotional person, but I would not function in an environment working only with robots" (973i). Working with robots is also considered something that can make the work more boring or depressing, and that socializing and talking to colleagues is an important part of the job. Several respondents understand that increasing contact with robots is associated with the risk of making work feel lonelier and more alienated—that is, that work is perceived less meaningful and detached from the surrounding world (c.f., Donahue 1996). On the other hand, one of the researchers claims that what we consider to be social and friendly human behavior is something mechanical and something that could be programmed in the robots of the future. "The robots would probably be much nicer than the average human; they could ask you about your weekend" (568r).

Some of the industry managers and researchers from the technical university express a concern that operators might be skeptical of working in close collaboration with robots (931i; 942i). One manager at Volvo GTO (942i) says:

> *There are certainly some [operators] who are skeptical, they are concerned over safety, and keeping their job [...] There are probably many worries. But my experience is that if you install and calibrate the system in a way that feels good for the operators to work with, then I do not think this will be a significant problem for the operators.*

This quote reflects a general understanding among both researchers and managers in the industry that there is some initial skepticism among the operator concerning both safety of the equipment but that this won't be a significant problem if it is dealt with in a good way.

In line with the second part of the quote above, the operators' views are not understood as a major obstacle for installing intelligent automation in the factories. From the perspective of the researchers and management in Volvo GTO the general understanding is that the operators are pretty positive of these changes (154i), confirming the understanding of the three operators interviewed for the report. A manager says: "after playing with the robot for a while and seeing that it stops when it should stop, they gain confidence in it. The safety representatives also think that safety is good enough in the showcases we had" (869i). Another manager says, "The operators we have been in contact with [cobots and ATRs] have no problems. They are not afraid of technology" (593i). The general understanding among managers is that if the operators are involved in the implementation process and safety evaluation of the work station, and if they have sufficient time to learn and gain confidence in the new machines, a possible initial skepticism among the operators will not be a problem. The general understanding among the managers is that the fear of losing the job is the biggest concern for operators in introducing intelligent automation compared to safety issues and insecurity in dealing with the technology (949i; 869i; 973i).

So, the operators' initial resistance or fear is generally not considered a major obstacle. But this makes it important to deal with the technology transformation in a good way. While there might be some initial concerns among the operators, the managers feel confident that these can be dealt with by introducing the new technology with the operators' perspective in mind. An important aspect of introducing the technology is that operators receive the proper education for operating the robots and that it is presented in dialogue with the operators. Several respondents stress that it is essential to include operators and the union at an early stage of introducing new technology (154i). The management considers it important to communicate upcoming changes in a positive way, and that they choose good places for making the initial installations, and communicate that the automation will remove boring jobs and potentially dangerous jobs to the operators. Furthermore, it is considered important to be open with future development; a manager says: "Being open is what is most important […] Nobody should feel that this is sneaked into the factory, and we are open about the fact that we are looking at these technologies, and we communicate the potential advantages. Most operators become interested if you are open with these things" (942i).

So, operators are generally optimistic about technological upgrades and changes. However, there are some concerns or worries that relate to the fear of being replaced by automation and, to some extent, to getting used to new technology and concerns over safety. Operators might be reluctant to work with equipment that makes their own decisions (or are perceived as taking their own decision). A negative perception among operators can also have a social aspect, i.e., if the number of human operators is drastically reduced, it is also removing social communication between humans, which is an important aspect of what makes the work meaningful or bearable to many of the operators.

5.9 The future of intelligent automation in the automotive industry

Predicting the future of intelligent automation is difficult as it is dependent on many contingent factors both within the organization and outside the organization. Global trends such as increasing protectionism, environmental regulation, and global pandemics might influence demand for products and preconditions for manufacturing. But given the current pace of development where manufacturers are getting more and more experience in using cobots and ATR:s, start to find suitable applications, and given a technology development and a price drop of robots, carts, and other equipment, an incremental increase of intelligent automation in production also in the final assembly of the automotive industry is likely.

A necessary precondition for intelligent automation is the development of commercially available products to make them suitable for automated solutions in final assembly. A manager in Volvo GTO says: "so far, I can say that we have much manual work because we have such a complex product. The product will be developed and maybe better designed for automation in the future. And when we get products that are made for automation [the change will come]" (593i). As discussed in the previous section, managers are much more optimistic about introducing intelligent automation in transportation and the sub-flows because it is easier to implement due to regulation and technical reasons.

Furthermore, cognitive tasks are considered to be possible to automate. A manager stressed: "Much administrative work done manually today will most likely be computer-based in the future. Apps and other applications will help us do routine tasks differently and more efficiently. It is only the imagination that sets the limit [for such development]" (931i).

However, given the perceived difficulties in integrating this technology in the existing processes of the factories and the compatibility issues with current technology, it is unlikely that we will see a rapid increase or radical changes in production in the near future. Most interviewed people recognize a continuous need for humans in the production in the factories, especially within the final assembly. Some tasks are considered too difficult or expensive to automate, and the organization has to deal with the legacy of their production units and products. Most managers stress that they cannot envision a completely automated final assembly. A manager says: "even if our products change in 20 years, there is a legacy left in the product that will make it difficult to automate" (942i) entirely. Given the advantages and disadvantages of automation discussed here, management in the factories does not see it as a comprehensive solution for every aspect of production. Rather than seeing intelligent automation as a solution for the entire production, they see it as a more realistic development to find specific tasks that can be automated—but as discussed earlier, it is relatively simple solutions with a low degree of intelligence that they envision.

The introduction of this report discussed how manufacturers of intelligent automation recognize a possibility to make the production more resilient and easier to adjust to changes in production—what is referred to as agile automation. While acknowledging a need to make faster adjustments of the production in the future to deal with a more rapid change in products (488i), cobots and ATRs are generally not perceived by the managers at Volvo GTO as a remedy to this problem. Most of the respondents in the interviews do not consider these technologies as a solution to deal with uncertainties regarding future product variation and demands or as a way of dealing with risk in investments. First, these solutions are not considered flexible to any actual extent. Although cobots and ATRs are considered to be easier to program, it is not regarded as easy to make them work in the conditions of the existing factories. And making swift changes in production using these technologies is generally not understood to be easy from a technical or a regulatory point of view.

Regarding the future of production, there are so many uncertainties and contingencies regarding the future of the factories that increased flexibility in production may not provide a solution. Human operators are considered more flexible, in the sense that they can adjust to product variations, compensate for error margins in product and positioning of products, they can swiftly adapt to a new work task, and, especially if they are hired through a staffing agency, they can be let go on very short notice if there is a drop in demand. A manager at Volvo GTO summarized the general view quite well when saying: "In our part of the production, humans are very much needed. The increased customization of the vehicles we produce speaks against increased automation. In a way, it is becoming more and more difficult to automate" (949i).

When trying to predict the future of intelligent automation in the final assembly in the automotive industry, many contingent factors are hard to predict—both within and outside the organization. This includes technological development, adjustments of regulation, and political decisions made on both an EU-level and a Swedish national level (as well as other regulations that affect the production and requirements of the products in other parts of the world). But a likely scenario is that we will see an incremental increase of intelligent automation in final assembly—especially in the sub-flows and transport aisles. It will take time to find suitable solutions and promising applications, realize the potential of this technology, and see how it can change current production limitations. As seen in the presentation of the empirical material above, some stakeholders understand human-robot collaboration to be a dead end and propagate for full automation of final assembly. This might be a viable solution for some sectors of industrial production. However, it doesn't seem like a realistic solution within any near future for the final assembly in Volvo GTO as it would require substantial changes in both the assembly lines and in product design for this to work.

A stakeholder working in a government organization stresses in the interview that it will take time before the industry will find the best ways of utilizing intelligent automation. He says: “When a new technology is coming, it takes a while before you can use it to its full potential, and that will also be the case with collaborative robotics” (222o). He says that it will take time before the involved actors understand “what limitations in product design and construction are removed by such technology” (222o). The benefits of such technologies and intelligent design will be evident once actors realize what changes in product design and production are facilitated. Also, regulation changes are expected to take time. One of the stakeholders at a government agency says: “It is easy to say, 'we do not keep up, but regulations also mean that we must come to mutual agreements between different actors at EU level” (205o).

6. INDUCEMENT AND BLOCKING MECHANISMS

So far, this report has presented and discussed stakeholders' views on the possibilities of introducing intelligent automation in the final assembly in the automotive industry, focusing on Volvo GTO, a large manufacturer of trucks. Based on the interviews, this section of the report presents perceived benefits and obstacles towards a successful and profitable introduction of intelligent technology in final assembly in the automotive industry. A table of factors influencing the infusion of intelligent automation in the organization has been compiled. This model for technology infusion is based on information provided in the interviews; while inductively constructed from this specific case study; it can be used to discuss technology infusion in other organizational settings and provide further research questions to be investigated more thoroughly in future research. The model also discusses critical areas of policy intervention (a topic discussed in Chapter 7). This section is divided into three parts, the first will discuss external inducement mechanisms (6.1), the second internal indictment mechanisms (6.2), and the third will discuss blocking mechanisms (6.3).

6.1 External inducement mechanisms

External inducement mechanisms refer to factors outside the organization that influence technology infusion; they are presented in the model's first column (Figure 2). A crucial external inducement mechanism is technological development other than the company's research. As seen from section 5.3.1, the technology readiness level of available equipment (for example, cobots and ATRs) is considered to be crucial for deciding on investments in intelligent technology. In the same fashion, the availability of competent integrators and service providers capable of dealing with the given technology is considered necessary for the company to invest in technology. External inducement mechanisms also include discursive factors (in the sense that they are not purely based on an evaluation of the technologies' capabilities). Respondents from Volvo GTO explicitly state that competitors' moves influence their way of thinking about new technology and contribute to an interest in intelligent automation. As discussed, these inducement mechanisms can be strong or weak, and there are also potential conflicting external inducement mechanisms. So, while some external factors positively influence investments in intelligent technology, industry stakeholders stress that other actors invest in conventional high volume and high-speed automation, which makes them reluctant to make significant investments in collaborative automation.

While people within the industry do not stress available research funding as a reason for technology infusion, many research and development projects are done in collaboration with the universities and are enabled through external research funding. Therefore, it is included in the model as an external inducement mechanism. Within the industry, it is also recognized that policy and other external discourse influence their view on technology; one manager, for example, states that the German concept of industry 4.0 strongly influences the interest in intelligent automation.

The external inducement mechanisms are not an objective category when influencing the company's decisions. For example, the perceived external technology development functions as a driving force rather than external technology development. For external inducement mechanisms to influence the decisions of a company, there must be responsiveness to such external factors. In the case of Volvo GTO, there is such responsiveness through the R&D department, but also by the fact that the managers in other departments within the organization continuously keep themselves up to date with the current development through reading industry-related magazines and information from the manufacturers, and through formal and informal networks within the industry. The information from the outside world is assessed in relation to the context of the own organization. For example, one manager talked about a successful installation of collaborative robots in a Renault factory in France but pointed to differences between that factory and the factory where he was working and said that such installations would be challenging to do in his factory.

6.2 Internal inducement mechanisms

The second column signifies the internal inducement mechanisms. The most crucial internal inducement mechanism is the prospect of creating competitive advantages for the company or the factory in question. The most obvious potential benefit is that it can lower the cost of production or increase the quality of the final product to such an extent that it makes its products more desirable for consumers either by improved quality or more competitive pricing. A reduced cost of production is not always the result of quicker and more efficient production; decreasing mistakes in production and improving ergonomics can also be economically beneficial. But advantages do not necessarily relate to reduced production costs; they can also be some other perceived benefit, for example, an increased capacity to deal with product variability, which can reduce economic risk.

Research projects into, and investment in, what is perceived to be state-of-the-art technology can also produce discursive advantages; for example, if research gains media attention, it can promote the company and the product brand. While explicitly stating that state of the art research is a way of attracting competent employees to the company, research and development in the production is also a part of product branding as they promote such research in magazines and web pages. However, while such discursive disadvantages can motivate research projects and small-scale investments, it is insufficient to encourage more significant investments. As discussed, investment in technology in production is not understood to be as crucial as technology investment that is directly visible in the final product.

The last box under internal inducement mechanisms (Figure 2) concerns the relation between the external inducement mechanisms and the internal. While technology development, to take one example, can be described as an external inducement mechanism for technology infusion, it does not automatically lead to this. There must be functions and mechanisms within the company to keep up with the technology development in the outside world and to find and evaluate potentially relevant technology. For any specific company, the technology readiness level is a "perceived" readiness level based on their mechanisms for evaluating technology. The same goes for all of the other categories under the headline of external inducement mechanisms, i.e., the perception is dependent on knowledge about things that are going on outside the organization. As shown in the interviews with the management within Volvo GTO, they have continuous communication with other actors and other factories. They also state that this influences how they work with new technology (see section 5.1). In the interviews, the stakeholders also say that they try to keep up with technological development, for example, by reading magazines (973i) and in other ways, as discussed above. They also gain knowledge about state-of-the-art research by collaborating with the universities. University stakeholders also recognize the importance of engaged industry stakeholders interested in keeping up with development; a researcher talks about Volvo GTO and stresses, "Volvo GTO is an important actor with visionary people in the organization that find the current development exciting" (568r).

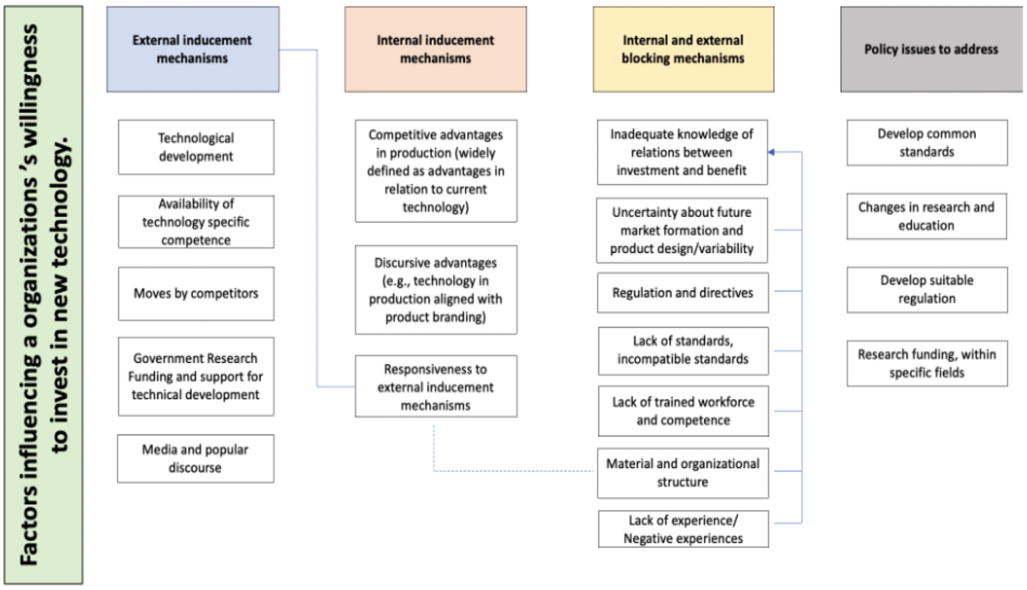

Figure 2: Factors influencing technology infusion of intelligent machines inductively identified in the interviews. All the categories in the white boxes are inductively identified through the interviews with stakeholders[7].

6.3 Internal and external blocking mechanisms

The third column internal and external blocking mechanisms, refers to all those factors that reduce the prospects of introducing, in this case, intelligent automation into the production of the factory. Corresponding to the most important inducement mechanism, the strongest internal blocking mechanism is an understanding that benefit will not exceed the cost of investments or a considerable uncertainty about whether or not they will be able to recoup investments. The other boxes in this column all relate to this first box being factors that might negatively influence the perceived possibility to make investments beneficial for the company and its shareholders. These factors include current regulation that in this study is perceived to

7 In identifying enabling factors and blocking mechanisms this study is inspired by studies of innovation systems. Underscoring the importance of identifying the structural elements facilitating and restraining the possibility of achieving innovation, including actors, networks and institutions (e.g., Bergek et al. 2008). This perspective stresses the importance of identifying institutions such as culture, norms, laws, regulation, and routines being crucial for any technology to diffuse. While this is not a study of an innovation system as such, but focuses on one organization and associated actors' view on the introduction of a technology, this approach has been useful for identifying key issues, and institutions creating a framework for the inquiry of the study.

be an obstacle to creating efficient, intelligent automation solutions in the factories (see section 6.5 for details).

The material and organizational structure relate to both the organizational capacity to deal with transformations, as well as the existing factories and technology that might be incompatible with new technology, and change might require a considerable conversion cost.

Furthermore, a blocking mechanism closely related to the material and organizational structure is the availability of competent workforce. The perceived lack of competence is understood as an obstacle to the possibility of making intelligent technology work in the factory. Also, previous negative experiences can be a blocking mechanism for the will to invest in such technology (both experiences from within the organization and experiences from other actors within the industry). The experiences with the existing collaborative installation are often used as an argument against increased automation by the interviewed industry stakeholders. Simultaneously, it is argued that a critical level of automation is required to make automation and, in an extension, intelligent automation to seem like a viable alternative in production. This means that such trails can positively affect increased automation in the long run, even though there are some initial negative experiences.

7. WAYS FORWARD

Already 40 years ago, intelligent and flexible robots that could adapt to changing conditions were expected to be available in the not-so-distant future. However, there were still some obstacles to using robots intelligently and flexibly (See section 2 of this report). The technology has developed much since then, but the views on benefits and obstacles to intelligent automation expressed by the respondents to this study are remarkably similar. In recent years, AI technology has "produced impressive results in object recognition, translation, and speech recognition" (Larsson & Viktorelius 2022). While AI-powered control systems can benefit industrial production by facilitating adaptive control systems and intelligent coordination of multiple devices, it has made a limited impact on industrial production. Several of the reasons for this have been discussed in the previous section of this report. This chapter suggests ways to enable such development among industry stakeholders with this as background.

7.1 Policy issues to address

Enabling factors for intelligent automation include overcoming technical, organizational, and regulatory challenges. Some of these challenges are relevant for policy intervention. While technology development is mainly an issue for industry actors and engineering science, technology development can also be facilitated through policy and government intervention. The discussions often highlight the need for common standards regarding the safety and technical compatibility of products and for transmitting information between different systems in the factories. While this primarily is a concern for actors within the industry, standardizations can also be an area for policy interventions, for example, by government or supranational intervention to change current standards or establish new ones on the EU level and beyond.

But state and supranational bodies (e.g., the EU) can also help facilitate development through continuous research funding into developing state-of-the-art technologies and applied technology to help promote competitive industries. Many of the interviewed stakeholders widely recognized a need for increased competence in automation. Government and government bodies can provide additional funding, and other forms of incentives can be offered by government and government bodies for encouraging technical universities and colleges to increase education relevant to intelligent automation.

7.2 Regulation and safety

Based on the perspectives of the stakeholders as well as an analysis of current regulation and safety standards, Atieh et al. (2022) identifies the following problems with current regulation: i) existing categories and conceptualizations used to guide safety evaluation are problematic, ii) intelligence and autonomous aspects of collaborative systems are not sufficiently addressed, iii) current standards do not enable evaluation of the tradeoff between safety, efficiency and flexibility, and iv) the regulation has a lack of focus on active safety and using the control system as a safety measure.

While safety is not considered a significant obstacle among the interviewed stakeholders, the regulation is generally seen as not being well adjusted for intelligent automation. It is not perceived to align with norms of acceptable risk, as the devices are believed to make factory work safer. Yet, they are more difficult to introduce due to current regulations. In other words, it is not aligned with the norms of the respondents, i.e., their understanding of what is right and wrong. On the contrary, they find that the safety directive and regulation make it more challenging to increase safety in the factories. Most of the respondents in all categories of stakeholders recognize the need to improve or change current regulation to facilitate intelligent automation on a larger scale in the factories. How to solve these issues in a way that is satisfactory to all actors and can be applied to the current regulatory system is a question that needs further investigation both on a national level and on an EU level. Further research on attitudes and dialogue with involved stakeholders is also required.

As an initial starting point, the difference between safety in traditional collaborative robots and intelligent human-robot collaboration is analyzed by Atieh et al. (2022). A new safety approach is suggested, called Deliberative safety, which allows humans and robots to switch between different safety measures based on the need for flexibility or efficiency to reach production goals.

Another crucial enabling factor for intelligent automation would be a change of regulation that could make the process of CE-labeling and risk assessment for intelligent systems more efficient and regulation that would enable intelligent robots to work at a faster pace in areas with humans.

7.3 From traditional to intelligent automation

While regulation and future technology development are important aspects of facilitating intelligent automation, it will also require a change of mentality or perspective among the industry stakeholders. Throughout the interviews, it has become evident that devices such as cobots and ATR are used much in the same way as traditional automation—programmed to perform a single repetitive task. As an industry stakeholder says: "When we install a collaborative robot, it rarely does any collaborative work [...], it is very rare for us to find applications where humans and machines can collaborate” (949v).

A stakeholder in government with extensive experience of the industry criticized the focus on speed and lifting capacity when discussing the benefits of cobots. He described a workstation in a car factory where a cobot glued the inner ceiling while human operators performed other tasks simultaneously. He says: “And the robot was not faster than man, it was maybe even a little slower. But if the work that has to be done by the robot went slower than any human operator could have done, it does not matter because the human operator has other tasks at the station that take the same amount of time. [...] It is not a question of how fast you can do it, but it is a question of whether it is fast enough for the current application” (222o). Consequently, if the workstations are designed well enough, such applications can add much value to the production.

While flexibility is discussed as a potential benefit because units could be moved between workstations and perform different tasks, the industry stakeholders do not understand intelligent automation as an adequate response to global trends and uncertainties about the future in making the production more resilient. Instead, low product variability is understood as a prerequisite for introducing intelligent automation. When asked about intelligent automation, most industry stakeholders reproduce a view of traditional automation that is only beneficial when there is low variability and repetitive movements. If cobots are used and evaluated as traditional automation and industrial robots, they will inevitably be a less suitable alternative. A researcher says:

> *[The industrial experts often have the] experience that most cobot installations are inflexible, inefficient, and expensive, or that they are just small, weak, and slow. This discord probably exists due to bad experiences of immature technologies. They are trying to use a cobot without an intelligent control system with perception capabilities, resulting in industry stakeholders failing to see the potential benefits of intelligent and collaborative automation. (876r)*

A new type of intelligent control is necessary to increase the flexibility and general usability of intelligent technology. Intelligent automation must be both flexible and efficient; it must be highly adaptive, cope with unforeseen events, handle variations of parts and resources, interact with both humans and other robots, and have a significant degree of freedom to perform complex operations. It must also focus on how humans and non-humans can maximize the performance taking its departure in the qualities and capacities of the humans and robots, respectively. Such flexibility can only be achieved using an AI-driven control system and advanced sensors.

To better understand the difference between traditional and intelligent automation, we will refer to a typology of how the human brain can function flexibly. Based on neurologic studies of how humans make decisions, Schall (2001) isolates three significant processes in the brain: deciding, choosing, and acting. "Decision" in this context refers to "covert deliberation about ambiguous or conflicting alternatives," entailing the complex planning processes of the brain. "Choice" refers to the "final commitment, an overt action performed in the context of alternatives for which explanations can be given in terms of reasons and desires." This distinction between the planning process and the final choice is an explanatory model for understanding the difference between traditional and intelligent automation.

A traditional automation system does not have a mechanism to take deliberate "decisions" but will make "choices" concerning what actions to perform based on predefined functions, often by taking steps in a predefined and fixed sequence. Each action is pre-programmed, and, in most cases, all motions are performed the same way in repeated sequences, which requires everything to be in highly accurate positions. Since each choice is pre-programmed by an engineer when the system is designed, the system cannot adapt or change its execution after being programmed. If something happens unexpectedly, the traditional automation system will stop executing or break down. It is possible to plan for unexpected events while programming a new system by creating a program that has more alternative actions to choose from. Even though such a system may appear to make decisions, to make the system truly intelligent and efficient, it must have an online decision process that can plan what task to execute to handle unforeseen events, be able always to reach various goals, and to let humans and robots truly plan, decide and act together.

Aligned with this view, Golderberg (2019) states that "I propose a constructive and inclusive alternative: 'multiplicity,' where humans collaborate with AI and robots to complement each other mutually." This vision summarizes the need for a new intelligent control system that includes both machines and humans in one system. As Malone (2018) states, "we should not say 'computers in the loop,' but rather 'computers in the group,'" focusing on how each component of an automation system can be used to its most full capabilities. Such a shift in perspective and design of automation systems is required to utilize the benefits of cobots, ATRs, and human-robot collaboration in the final assembly of the automotive industry. As automation of final assembly will require extensive changes throughout the organization, close cooperation and mutual understanding between industry stakeholders and researchers are required to develop technical solutions that are useful to the industry.

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