Robotics4EU

Boosting Wider Adoption of Robotics in Europe //

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Responsible Robotics & non tech barriers to Agile Prodution

This report is based on R4EU research, as well as second-hand data.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017283

Table of Abbreviations and Acronyms

Abbreviation	Abbreviation
AI	Artificial Intelligence
AP	Agile Production
Cobots	Collaborative Robots
EU	European Union
HRC	Human Robot Collaboration
HIPAA	Health Insurance Portability and Accountability Act
IFR	International Federation of Robotics
PbD	Programming by Demonstration
OSHA	Occupational Safety and Health Administration
GDPR	General Data Protection Regulation
GPSD	General Product Safety Directive
VR	Virtual Reality
SMEs	Small & Medium Enterprises
PII	Personal Identifiable Information
OpenMos	Open dynamic Manufacturing Operating System for Smart Plug-and-Produce Automation Components

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1. Introduction

This report serves as an introduction to responsible robotics for Agile Production (AP) readers. It does so by explaining the current state-of-play of robotics in *Agile Production*, including an overview of how current issues relate to the development of socially acceptable robots in Agile Production, and gives references to resources relevant to the responsible robotics community.

This document thereby presents the main findings drawn from research and stakeholder engagement activities (desktop research, co-creation workshops, etc.) conducted among robotics community members and policymakers during the Horizon Europe funded Coordination and Support Action project Robotics4EU (2021-2024)[1]. The main objective of the mentioned activities was to gain insight into the main issues in the deployment of robotics, including the current practices, shortcomings and the needs and readiness of the stakeholders as of 2023, but also on the resources available in support of building responsible robots.

More specifically, the focus of Robotics4EU is on the development of responsible robots and the social acceptance of robots in Healthcare, Agri-food, Inspection & Maintenance, and Agile Production. Below is the report on AP which introduces the state of play in the sector, relevant resources, and outcomes of Robotics4EU activities in this particular sector.

1.1. About Robotics4EU

The Robotics4EU (2021-2024) project aims to ensure a more widespread adoption of (AI-based) robots in healthcare, agri-food, inspection and maintenance of infrastructure, and agile production. This goal is reached through the implementation of responsible robotics principles among the robotics community that results in societal acceptance of robotics solutions in all application areas.

Robotics4EU will create and empower the EU-wide responsible robotics community representing robotics innovators from companies and academia in the mentioned fields, but also citizens/users and policy/decision makers by raising awareness about non-technological aspects of robotics (ethics, legal, socioeconomic, data, privacy, gender), organising community building and co-creation events that bring together the robotics community and citizens, advocating for responsible robotics among all stakeholder groups, developing a responsible robotics maturity assessment model (a compass for responsible robots) and bringing the project results to relevant standardisation bodies.
Robotics4EU will implement the following set of activities:

1. assessing the needs and developing a responsible robotics maturity assessment model that is a practical tool for the robotics developers and helps them to strategically plan the uptake of legal, societal and ethical aspects of robotics;

[1]Principles of GDPR were followed throughout the tasks completed to reach the objectives of this deliverable.

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2. empowering the robotics community by organising capacity building events in healthcare, agri-food, agile production and infrastructure and maintenance;
3. ensuring citizen acceptance of robotics (via citizen consultations) and assessing robotics ideas and applications provided by the industry with end-users (via online consultation and co-creation workshops);
4. reaching out to the policy makers by compiling a responsible robotics advocacy report, organising a high-level policy debate and transferring the results to the standardization bodies.[2]

1.2. Responsible Robotics

In the context of the Robotics4EU project, responsible robotics refers to robots that consider the values and expectations of the society that needs them. This concept plays an important role in Robotics4EU as safer, more considerate, durable, affordable, and practical robotics solutions – responsible robots – will be the central component in avoiding, limiting, and/or removing non-tech barriers that are currently in the way of the widespread adoption of robots.

The project employs various methods to promote responsible robotics in different fields of robotics, including but not limited to: citizen involvement in robotics development, policy recommendations & advocacy plans, and also the creation of a maturity assessment model named Responsible Robotics Compass (RoboCompass).

This tool, developed by Robotics4EU, will help to assess and determine the maturity of non-technological aspects of a robot in development, regardless of its area of application. It focuses on Legal, Data, Socioeconomic, Human experience, and Sustainability markers, considering how the technology is developed, which internal and external processes are in place, how it interacts with its user, and other relevant risks and risk mitigation measures.

It is a tool that helps companies to 1) identify their level of development along Legal, Data, Socioeconomic, Human experience, and Sustainability dimensions by assessing risks and mitigation steps, 2) receive recommendations and tools on how to improve, 3) track progress over time. This ensures trust and societal acceptance – all of which are expected to safely and widely adopt robots among their intended users.

In support of developing the maturity assessment tool in discussion – Robotics4EU executed a wide range of research and engagement activities (incl. stakeholder needs' analysis, interviews, surveys, co-creation workshops and policy workshops) to collect information on current issues as well as solutions regarding the socio-economic, ethical, data, privacy, and legal matters from policy makers and the robotics community (both the producers & consumers).

These insights are gathered into four area-specific introductive reports such as the one at hand that (a) presents the general application and trends of 2023, (b) describes the common

[2]Project information from CORDIS: https://cordis.europa.eu/project/id/101017283

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non-technological challenges and barriers, considering a variety of dimensions, including issues and worries related to socio-economics, ethics, privacy and legal matters; (c) and highlights relevant suggestions, guidelines, resources and initiatives relevant to build a stronger responsible robotics community.

2. State of Play within Robotics for Agile Production

Contributors: Silvia Ecclesia

This report functions as an introductory guide to responsible robotics for readers with an interest in Agile Production. It does so by elucidating the present state of play in AP, offering an overview of how ongoing issues intertwine with the development of socially acceptable robots in the AP domain, along with an exploration of the tools and resources accessible to facilitate this progression.

2.1. Agile Production moving towards Industry 4.0

The birth of the term agile production can be dated back to the 1990s, when the "Agile Manufacturing Enterprise Forum" was created with the mission of reviving the manufacturing sector in the US by introducing agile strategies. The change from lean production to agile production has not been a drastic one, but rather a shift in focus. While lean production emphasises eliminating any potential waste in the production process – intended as a waste of resources but also a waste of time and productivity – agile production poses a greater emphasis on flexibility (Quamar, Hall & Collinson, 2018).

In the context of the Robotics4EU activities, we have adopted the definition of agile production as "the processes, tools, and training needed to react swiftly to customer needs and changes in the market while still being able to control cost and quality. It involves a strategy for incorporating velocity and flexibility with a make-to-order or configure-to-order production process."[3] This flexibility is to be rooted in automation and informatization of manufacturing processes which can boost the achievement of greater flexibility and adaptability.

Within the literature, agile production and agile manufacturing are often mentioned in the broader context of the Fourth Industrial Revolution, or Industry 4.0, which is a concept introduced in 2011 referring to the "intelligent networking of machines and processes for the industry based on CPS [Cyber Physical Systems] – a technology that achieves intelligent control using embedded networked systems" (Xu et al., 2021). While the emphasis is on connectivity and network, Industry 4.0 is a business model including elements of flexibility, adaptability, optimization, data integration and security. Therefore, agile production is one of the key components of Industry 4.0.

Most recently, the concept of Industry 5.0 has also emerged indicating a willingness to abandon the exclusive focus on digitalization proposed by Industry 4.0 and adopting a more human-centric approach. According to the Industry 5.0 principles, industrial growth is a means for achieving societal goals; therefore, production should respect the boundaries of our planet and place workers' well-being as a central concern (Xu et al., 2021). In this framework, robotics is understood in symbiosis with human workers and with attention to the

[3] Robotics4EU Grant Agreement

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safety and quality of the work environment. Being a very new model, Industry 5.0 is only now making its way into the industry, however, the effects of this change in perspective can already be seen in the emerging robotics trends.

Agile production is tightly linked to the concepts and principles of Industry 4.0 and 5.0, therefore, discussions about robotics for agile production cannot be separated from these models.

2.2. General application

Robotics are an integral part of agile production since they can provide increased efficiency and productivity as well as precision and flexibility. The automotive industry has historically been one of the first industries to adopt robotics for process automation, however, robots are now employed in many other sectors of production. According to the International Federation of Robotics (IFR), the global average for industrial robots per 10,000 manufacturing workers grew from 66 in 2015 to 85 in 2017 (Atkinson, 2019).

Among the major benefits of employing robotics for production is the often mentioned positive impact that they can have on the safety and quality of the work environment. Robots can take on dull, dirty, and dangerous jobs (3D jobs), thus, improving safety conditions and encouraging employees to take on more creative and skilled jobs in engineering, programming or maintenance. In addition, robots can improve a business's efficiency and productivity, allowing it to stay competitive in the international market. The higher flexibility and adaptability provided by robots permit businesses to meet the market's demands. Increased adoption of robotics has been found to result in an increase in GDP's annual growth and labour productivity across 17 countries (Atkinson, 2019).

In the long term, the introduction of robots also lowers production costs, providing an alternative to offshoring and fulfilling capability gaps where hiring talent is difficult. Besides, a potential socioeconomic vector for wider adoption of industrial robotics is **its contribution to sustainable development**. It is recorded in the literature that industrial robot applications significantly reduce carbon intensity, thanks to their contribution to energy efficiency, especially in developed countries and in manufacturing, agriculture, and electricity, gas, and water supply fields (Li et al., 2022). Nevertheless, European countries lag in terms of robotics adoption compared to Asian countries, with South Korea being the most advanced robot adopter in 2017 (Atkinson, 2019).

According to the analysis of Fernandez-Macias et al. (2021), robot applications in Europe are respectively in the fields of handling operations and machine tending, moving objects with precision (55% of all European robots), welding and soldering (22%), and assembling and disassembling (5%). Body welding has been one of the first tasks to be robotized in the automotive industry and welding is still one of the main tasks performed by robots today with the robot welding market size growing at a compound annual growth rate of 11.17% (Kim et al., 2023). Robots are also often used for cutting, measuring, spray-painting, sanding, or packing.

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Autonomous mobile robots are also becoming more diffused to move heavy materials or boxes around the shop floor. In addition, thanks to the advancements in machine vision, machine learning, and artificial intelligence, robots for agile production are becoming increasingly autonomous in performing their tasks. They can sense the environment around them, move independently, perform high-precision tasks and learn autonomously.

2.3. Trends

Human-robot collaboration (HRC) is one of the most prominent trends in robotics for agile production. It entails a close collaboration between humans and robots instead of a replacement, in line with Industry 5.0 principles. HRC can take on various forms: for example, workers could oversee the robot's work while avoiding performing dangerous tasks or could "teach" the robot how to perform a task while doing it in parallel.

Cobots (collaborative robots) allow for more flexibility which in turn allows businesses "to meet the market's demand for high product variability, diversity, and even batch size 1" (Halim et al., 2021). Cobots are usually smaller and lighter than traditional robots because they need to be easily manoeuvrable by humans, and they are also usually easier to re-program. The share of collaborative robots in the total industrial robot installations has been increasing every year since 2017 (Berx et al., 2022).

Linked to HRC, another trend in robotics for agile production concerns robot programming. Robot programming time is one of the biggest challenges in the deployment of robots. Traditional online and offline programming methods require a lot of time, resulting in plant downtime, and are not in line with the principles of agile production. Low Code and No Code solutions rooted in HRC, also called **Programming by Demonstration (PbD)**, emerged as a solution.

Low Code and No Code programming relies on HRC to allow employees with no knowledge of programming to reprogram robots through hand guiding, gestures, or voice. Hand guiding is one of the most common programming methods for cobots, where the worker guides the robot arm in doing the new task, however, it requires a high physical effort and can result in low precision. Innovative solutions are moving towards the use of gestures, captured through haptic sensors, or voice for programming (Halim et al., 2021).

Developments in machine-vision, speech recognition, Artificial Intelligence (AI) and Virtual Reality (VR) are accelerating Low Code and No Code programming methods. These new methods will decrease the barriers posed by long programming times making cobots more accessible to SMEs (Small & Medium Enterprises) and allowing for increased flexibility and customization, in line with the market's demands.

Overall, since the push to transition to an Industry 4.0 model, robotics for agile production are moving towards **higher connectivity through integration with cloud systems and Big Data**. HRC and increased robot autonomy are also becoming more diffused thanks to advancements in machine vision, machine learning, speech recognition and AI. Smart Factory is becoming a common concept among manufacturers. The factories of the future are expected to be characterised by high robot-robot and human-robot connectivity and exploitation of new technologies for greater efficiency, productivity and adaptability.

3. Challenges and Barriers to Wider Uptake of Robotics Solutions in AP

Contributors: Öznur Karakaş

3.1. General limitations to successful market entry and adoption of robots

According to Eurostat (2017), one-fourth of European industries incorporate robots into their operations. Industrial robots are more commonly employed than service robots. The latter is primarily used in warehouse management (44%), transportation of people and goods (22%), cleaning and waste disposal (21%), and assembly works (21%). Conversely, as mentioned in the previous section, industrial robots are predominantly concentrated on tasks such as handling operations and machine tending, welding and soldering, and assembling and disassembling (Fernandez-Macias et al., 2021). Despite significant technological advancements, this depiction highlights a relatively limited adoption of robots, even within industrial settings.

Basic limitations to wider adoption of robots include **safety**, initial or operational **costs** related to constant reliance on software programmers, maintenance and service requirements (the risk of malfunction) and **limited flexibility.**

The high implementation cost of robots is known to be an impediment for, especially, SMEs (Williamson, 2119). The large initial investment, which includes expansive hardware such as robot manipulators and additional sensors, uncertainty about costs and lack of expertise are recorded to be the main barriers that prevent wider adoption of robots, especially by SMEs (Buerkle et al., 2023). Programming robots, requiring constant supervision of highly skilled employees, on the other hand, remains a general challenge to overcome. In order to avoid the risk of malfunction, leading to safety issues, robots must also be regularly maintained, which is added to the operational cost.

Industrial robots mostly have limited mobility, and one of the most important technical limitations to wider adoption of robots is **motion planning**. Motion planning refers to the process of specifying mobility from a current pose to a desired pose. This is of utmost importance at a time when collaborative robots are being introduced to the market.

Among the non-technological limitations, **fear of job loss/replacement** continues to pose a threat to wider uptake of robotics. Blanas et al., analysing the impact of industrial robots on demand for workers of different education, age and gender in 10 high-income countries and 30 industries, indeed report that software and robots reduced the demand for low- and medium-skill workers, the young and women, especially in manufacturing industries, otherwise raising the demand for high skilled workers, older workers and men, especially in service industries (Blanas et al., 2019). This situation warrants further attention, especially with respect to its gendered implications. While the impact of robots on employment is indeed

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generally conceived to be negative “either on overall employment or specifically for the low-skilled", there exists research (Klenert et al., 2020) which finds “no evidence that robots reduce low-skill employment in the European context” and “even a positive correlation between robot use and total employment in Europe between 1995 and 2015” (Fernandez-Macias et al., 2021). Fernandez-Macias et al. (2021) also put forward that current industrial robot applications are far from having a disruptive effect on employment. They rather argue that “the vast majority of current European (and worldwide) industrial robots perform essentially the same type of operations as previous mechanisation and automation technologies, replacing labour input in routine tasks that involve physical strength and dexterity” (p. 79). Since physical strength and dexterity tasks in Europe were already very low in 2016, according to Eurofound results, the authors don’t anticipate current automation to cause a meaningful impact on employment patterns. Furthermore, although current robotics solutions might be able to perform these tasks more flexibly and precisely or undertake more complex operations in a slightly more autonomous way, they argue that they are not radically different from previous automation technologies.

3.2. Issues specific to Agile Production

Challenges to the social acceptance of robots largely depend on the sector they are designed for. Technology adoption is indeed context dependent (Sostero, 2020). Existing statistics concerning social acceptance and adoption of robots mostly give an idea of industrial robots and robots used in transportation (Östlund et al., 2023). In this picture, it is relatively easier to gauge challenges to the social acceptance of robots in agile production when compared to other sectors.

One of the biggest challenges manufacturers face in times of agile production continues to be budgeting for **the cost** of the system. Along with the large upfront investment required for the installation of industrial robots, programming more and more autonomous robots requires a constant need for highly skilled employees. According to the Massachusetts Institute of Technology (MIT) The State of Industrial Robotics: Emerging Technologies, Challenges, and Key Research Directions Report (Sanneman et al., 2020), although robot hardware has become cheaper, introducing automation to a manufacturing line continues to be expensive. Hence, the cost of integrating automation into existing production lines remains a challenge. While large manufacturers find it expensive to integrate industrial robotics into their 15 to 20-year-old technologies and infrastructures, SMEs often find both the large upfront and integration investment prohibitive. It is for this reason, among others, that Low Code and No Code Programming, discussed in the previous section, has become a current trend. Another response to this barrier is the servitization paradigm, marking “a shift from traditional product-based business models towards rentable services" (Buerkle et al., 2023, p. 2).

Safety stands out as another challenge for the wider adoption of robotics solutions in agile production. The contemporary world witnesses a shift from workplaces with robots that do routine work to workplaces with more advanced AI-enabled robots. These robots, also called autonomous or collaborative –cobots (Vysocky and Novak, 2016)- are distinguished by their capacity to interact with people and the environment (Howard, 2019). Yet, this heightened autonomy also brings about an increased risk of collision with human workers.

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Ethics

The most important ethical issue related to robotics for agile production is the afore-mentioned **safety** risk. While robots are getting more and more autonomous thanks to advances in AI technologies, their higher interaction with people and the environment poses new safety issues. The shift to collaborative robots in workplaces indeed results in increased safety risks, including collision risk, due to the growing autonomous movement capacity of AI-based robots.

One advantage of the shift towards cobots is enhanced learning among robotic devices enabled by cloud connection, also called “cloud robotics” (Kehoe et al., 2019). This leads to “universal robotic upgradability” on a cloud-based network thanks to which any upgrade in a robot can be accessible to other robots connected to the system. Nevertheless, one disadvantage of this shift towards cobots in workplaces involves **increased safety risks** associated with the enhanced autonomous manoeuvre capabilities of robots. This leads to **heightened collision risk**. Cobots are subject to existing safety regulations, which mostly focus on limiting the speed of the robot, or the amount of force it applies. These limitations may, in turn, adversely impact their adoption by companies.

It is also argued in the literature that even when the physical collision risk is significantly reduced to levels deemed ‘acceptable’, a **lack of trust** among employees or workers could still serve as a barrier to the adoption of cobots in workplace settings. (Fletcher and Webb, 2017). Fletcher and Webb (2017) raise questions about the psychological impact of the possibility of ‘safe’ collisions with robots on employees.

Yet another safety risk might result from the use of cobots in non-collaborative environments. This raises the need for clearly defining and restricting the usage areas of cobots to collaborative tasks.

Socioeconomics

The socio-economic barriers to the wider adoption of robotics in agile production involve, first and foremost, the afore-mentioned concerns around **job replacement and skill depreciation**, the latter having the potential to lead to constant need for upskilling and/or reskilling the labour force. As a response to this concern, collaborative robots are at times depicted as a means to support workers, rather than replacing them. The 2020 MIT Report on industrial robotics indeed underlines the fact that the interviewed companies were also keen to avoid laying off workers as a result of increased automation. They rather “largely focused on how to leverage the creativity of workers in conjunction with the use of new technologies” (Sanneman et al. 2020, p. 8). Furthermore, as discussed above, Fernandez-Macies et al. (2021) also underline the fact that existing or potential automation technologies have limited employment effects, despite the anxiety around job replacement. They attest to a radical incongruence between such projections and real-life employment figures, the latter pointing towards “slightly growing rather than dramatically declining general employment trends” (p. 76). They also make the point that the types of robots that are currently frequently utilised in European industry and across the world are not likely to be disruptive, hence creating a major discontinuity, when it comes to their automation and labour displacement potential.

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Data

Issues related to data protection and data privacy are among the most important non-technological challenges encountered in the agile production sector. In the literature, they sometimes overlap and are discussed along with ethical and legal concerns.

Data protection appears as a constant concern since key components of Industry 4.0 also imply high involvement of personal data (Onik et al., 2019). **Information leaking or breaches**, and concerns around **data protection** of personal identifiable information (PII) are significant barriers to wider adoption of Industry 4.0 processes which rely on automation-enabled flexibility. Onik et al. (2019) list major data issues around AI and Robotics as follows: no privacy standardisation for AI-based technologies, inefficient consent gathering from users and non-monitored AI-decision making, based on user profiling. In a workplace setting where humans interact and collaborate with cobots, it is indeed "inevitable for these robots to collect data from the human-robot system for performance monitoring purposes or simply as a byproduct of the system's informatics" (Fletcher and Webb, 2017). The current General Data Protection Regulation (GDPR) covers data protection also in this domain. Yet, it is anticipated that the jurisdiction of this regulation might, at times, clash with that of the new EU AIA.

Data privacy is also a concern, especially in industries where private companies need measures to protect data of commercial value. **Cybersecurity** concerns accompany data privacy concerns and pose challenges to the successful implementation of robotics solutions.

Legal

In their assessment of interactive robots with high Technology Readiness Levels (TRL), Östlund et al. (2023) state that social acceptance of robots largely depends on the impact of regulations within Europe. The findings of Presidente (2017), reporting a positive correlation between European Employment Protection Legislation and investment in industrial robots, attest to this point.

In a similar vein, it is also established that the lack of a common policy that would be applicable to all European countries might pose challenges to the acceptance of robots, given the diversity of regulatory frameworks across Europe. The adoption of a new set of regulations at the European level, commonly referred to as the EU AI Act, on June 14, 2023, might put an end to this fragmentation. Yet, it is yet to be studied how the new regulation would impact robotics in different sectors.

Lack of safety standards and regulations suitable for cobots stands out as a significant impediment to the wider adoption of collaborative industrial robots, according to the 2020 MIT Report on the state of industrial robotics (Sanneman et al., 2020). The existing safety standards mostly rely on limiting a robot's overall velocity and the force with which a robot may interact with a person. Yet, the report maintains that companies are reluctant to implement these technologies because the speeds are affected due to these safety standards. Hence, **reduced speed** stands out as a limitation to wider adoption of cobots. It is also recorded that "traditional approaches, such as speed and payload limitations, are less applicable with new

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and emerging safety systems"(p. 13). An example is smaller, payload-limited robotics arms which abide by safety standards that can restrict the amount of force they can apply. The report envisages the development of new safety standards, and alternative approaches to safety, which focus on designing the robotic arm itself in a way to avoid collision with a human. There exists a need for further studies to develop safety standards for cobots that wouldn't impede speed or productivity in the workplace.

Education & Engagement

If it is true that the current anxiety around job replacement resulting from automation is not grounded in reality (Klenert et al., 2020; Fernandez-Macias et al., 2021), it is of utmost importance to make an effort to detect the source of these pessimistic narratives and inform the public about the realistic scenario surrounding the impact of automation on changes in employment. Such narratives indeed pose challenges for the wider adoption of robotics solutions.

A second obstacle is the possibility for civil society to lag behind the pace of Industry 4.0 implementations in the workplace. It is indeed argued that vocational systems need to focus on curriculum development, teacher training and training of highly skilled workers for the labour market to better respond to "Cyber-Physical-Systems", within the context of Industry 4.0. (Atwell et al., 2020). Fletcher and Webb (2017) also underline the importance of properly informing machine operators and workers on the functionality and reliability of human-robot collaboration systems so that they are aware of both user protocols and levels of risk and mitigation measures. The lack of comprehensive information on the possible repercussions of human-robot collaboration in the workplace could indeed be an obstacle to the wider adoption of cobots in the workplace.

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Common Issues within Agile Production

Socio-Economic Analysis

- Fear of tech unemployment
- Loss of worker autonomy
- Rising skill gaps and skill depreciation

Ethics

- Safety and security at the workplace
- Lack of responsibility and accountability
- Lack of transparency & liability
- Human rights abuse

Data

- Lack of informed consent
- Lack of data control
- Vulnerability of cyber physical systems
- Cyberwarfare (social & political manipulation)
- Data theft or leakage (network security)
- Lack of comprehensive information on human-robot collaboration systems

Legal

- Intellectual property infringement
- Lack of safety regulations suitable for cobots
- Lack of global governance
- Lack of and lag in regulatory development
- Unclear and unharmonized regulations (inconsistent set of rules for human-machine cooperation)
- Lack of legal rights awareness related to data and technology

Education & Engagement

- Propagation of pessimistic scenarios around job replacement leading to human obsolescence
- Insufficient public engagement
- Education issues (lack of resources, knowledge availability and informal science education)
- Insufficient empowerment of the general public

Figure 1. Common issues in the adoption of robotics across areas as identified by the Robotics4EU project

3.3. Learnings from Robotics4EU

Contributors: Silvia Ecclesia

In 2023, researchers affiliated with NTNU conducted a series of workshops (four digital and one physical) on **the use of robots in agile production**, involving more than 230 participants.

Every workshop began with two keynote speeches by prominent researchers, developers, innovators, and qualified professionals in the area of robotics for agile production. They were then followed by breakout room discussions centred around the aforementioned five non-technological aspects of robotics for agile production or on different dimensions of one of the aspects.

We hereby introduce the recurring topics, concerns and ideas that emerged from these events.

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Societal issues

Fear of job loss and replacement are very prominent in robotics for agile production and can be highlighted as one of the major barriers to societal acceptance. Two of the keynote speakers referred to the immediate sense of fear and distrust that workers feel when robots are introduced in the workplace. Participants in the workshops also indicated job replacement as a major risk of introducing robots.

However, several keynote speakers agreed that the **fear of technological unemployment is not rooted in reality and can be considered rather irrational as it is not in line with the real consequences of involving robots in the workplace.** In addition, Sgarbossa (21st Nov. 2023, "Robotization of intralogistics for agile production and warehousing") mentioned that while many robots are already present in the agile production sector, we are still far from full robotization.

Increased involvement of operators at all stages of the automation process is necessary to **create a climate of trust** when robots are introduced and to reassure workers against fears of replacement. Human workers should still be at the centre of the processes of automation and the introduction of robots should be based on considerations of return on investment and increase in efficiency, flexibility and reactivity (Sgarbossa, 21st Nov. 2023, "Robotization of intralogistics for agile production and warehousing").

People tend to anthropomorphize robots and attribute to them human characteristics which then lead them to distrust and fear them or place overly high expectations. Both of these scenarios are not desirable for a positive introduction of robots; workers should be part of the full process in a completely transparent way which should allow them to have the correct expectations concerning the robot.

Generally, three counter arguments have been presented as a response to the fear of job loss: an emphasis on robots as collaborators; the benefits of robots taking on dangerous and unhealthy tasks; and the shift from a replacement rhetoric to one of upskilling or reskilling.

HRC is a prominent concept in the sector, proposed as a solution to fears of labour substitution. Three of the keynote speakers stressed the importance of talking in terms of **robots working in collaboration with people rather than as the replacement of humans.** For example, Dacal-Nieto mentioned that their mission is "extracting the best from humans and machines, which means not substitution of people but collaboration with people and preserving jobs." (Dacal-Nieto, 16th June 2023, "Social challenges in human-centric factories and the application of Industry 5.0 technologies")

Increased collaboration between robots and humans is believed to improve working conditions. Dvorak stressed the importance of **automation of unhealthy and unsafe tasks, improving the health and safety of workers** (16th June 2023, "RoboTwin - Upskilling Workers to robot teachers"). Dacal-Nieto presented a robotic solution based on an exoskeleton which would make straining tasks easier for humans and decrease the physical impact on their bodies (16th June 2023, "Social challenges in human-centric factories and the application of Industry 5.0 technologies"). During the physical workshop, three speakers presented robotics solutions for agile production and all three stressed the role of robots in supporting human needs and taking

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away boring repetitive tasks from them to allow them to do more meaningful work. Some participants also recognized that robots make the workplace more inclusive, allowing people to do tasks they would not be able to do without automation. For example, increasing working opportunities for people with disabilities.

Lastly, both keynote speakers and participants mentioned that the introduction of **robotics for agile production has been demonstrated to not lead to job loss but rather to job displacement – the upskilling or reskilling of workers** to do other tasks. One of the group discussions focused on the need to expand the scope of what people do in the workplace to allow them to work side by side with robots.

However, participants were often still sceptical about the positive impact of robotics on the labour market. For example, **presenting job loss as an inevitable consequence** of automation ("I think that jobs will be replaced, people will lose their job, it is inevitable") or **questioning its long-term effects on the workforce** ("Might the human workers be 'teaching' the robots to do perfect tasks, so that they can 'replace' them fully once this process is completed?"). Also, the rhetoric of upskilling or reskilling was seen as problematic by some participants as it did not fully consider its social dimensions. **Upskilling or reskilling requires a certain level of resources and education which is not accessible to everyone** ("people with different levels of education are more or less excluded from jobs that include robotics"). If we consider the context of agile production where robots replace low-skilled workers, it is difficult for those same workers to find other jobs ("How can people with low skills in the manufacturing sector find some other work to do which will not be automated in the future?"). Therefore, reskilling and upskilling have been identified as a potential solution **but it will require support from policy-makers to ensure it does not increase inequalities.**

Nevertheless, keynote speakers agreed on the benefits of introducing robotics in agile production. "Automation could bring a **60% decrease in costs**" and increase in efficiency and productivity which would allow companies to remain competitive (Sziebig, 22nd Aug. 2023, "Robotics in manufacturing: Trends and Opportunities"). **Low-code and no-code solutions based on voice or gesture commands are a main trend**, especially for SMEs and small-batch-size productions. Several speakers also presented examples from their work which stemmed from a request from workers themselves thus, showing how workers do need and welcome the use of robots when it supports them.

Among the most important challenges to the adoption of robotics mentioned by two of the keynote speakers were the high cost and time of robot programming. **Programmers can cost double the salary of a worker doing the robot's job and can take up to one month to fully fine-tune the robot's program.** Therefore, collaborative solutions are presented: robots commanded through motion, gestures, voice or more innovative solutions based on exoskeletons and cognitive augmentation. These findings are in line with the trends identified in the literature.

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Data issues

Beyond the fear of job loss, issues of data privacy, biased datasets, and cybersecurity were mentioned very often by workshop participants and speakers as major barriers to the acceptance of robotics for agile production.

Data privacy is a huge concern, especially in the context of cobots. Having robots working closely with humans raises concerns about the **data privacy of human workers**: What data is the robot collecting? For which purpose? And how are they used? These questions are not always answered by the robot developers and participants pointed to the need for greater transparency to protect workers and increase trust. This can, of course, be achieved through the implementation of existing European regulations protecting sensitive data.

Robots used for the area of agile production often collect commercial data, therefore, hacking is an important risk requiring high **cybersecurity** standards. This was highlighted by multiple participants during the breakout room discussions. Hacking might lead to data manipulation from external actors increasing concerns regarding employees' privacy and safety.

In addition, participants mentioned issues connected to the **representativeness of datasets** used for robot training and predictions. In the case of exoskeletons, there is a clear need for **mitigating gender bias** when developing these tools. However, discrimination due to bias can also emerge in other robot applications. For example, one keynote speaker warned about the possibility of sensor-based robots capturing workers' movements and not being able to recognize all body types (Maxwell, 24th Oct. 2023, "Effective human oversight of AI systems - key enablers and obstacles"). This might lead to discrimination and increased safety concerns for certain groups.

Wrong decisions based on biased data can be avoided through effective human-oversight and human in-the-loop, thus, asking humans to control and validate AI's decisions before implementation. This, however, requires humans to be able to identify biased outcomes, which is not always the case. For example, one of the keynote speakers mentioned the human tendency to be unconsciously overconfident in AI systems (Maxwell, 24th Oct. 2023, "Effective human oversight of AI systems - key enablers and obstacles"). Therefore, clear regulation is needed to ensure contestability of results and redress.

Legal issues

Legal issues are considered two-fold. **On one side, safety regulations are too rigid or restrictive, limiting innovation and posing a barrier to the adoption of robotics**. For example, robots working in hazardous environments need to comply with ATEX regulation, which does not apply to cobots, thus restricting their introduction for these tasks (Ladislav Dvorka, 16th June 2023, "RoboTwin - Upskilling Workers to robot teachers").

Similarly, the recent AI Act has been identified as not supportive of innovation: "There are many requirements, it's very detailed, it's very complex" (Vera Lucia Raposo, 2023, "I, Robot (AI-based robots under the AIA)"); "All these predetermined risk categories [...] lead to potential over-regulation" (Ebers, 25th Sept. 2023, "The AI Act: a truly risk-based approach for

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robotics?"). The existence of many different regulations that could apply to AI-based robotics for agile production leads to legal uncertainty, hindering their proper implementation.

On the other side, participants call for more regulations as regulations on the use of cobots are lacking. This was mentioned by three of the keynote speakers and is well in line with what is found in the literature as a hindrance to the use of cobots. To be more specific, participants mentioned the need for regulations addressing the fear of job loss ("A way to mitigate this [job replacement] is through government policy and things like UBI [universal basic income]").

Legal uncertainty due to lack of regulations persists also in the area of **criminal liability**. "As of today there is no specific offence for illegal acts committed against or through AI systems" (Schoulidou, 24th Oct. 2023, "Criminal Liability and Robotics: A Call for Transformation"). Consequently, the AI Act stresses the role of **human oversight for ensuring regulatory compliance and the contestability of decisions taken through AI systems, thus, increasing accountability** and dissipating some of the legal uncertainty surrounding robotics.

Environmental issues

While the environmental risks of robotics for agile production were not the focus of any of the keynote speakers, they were mentioned by the participants in the breakout room discussions. "We need a holistic use, management or ideas for robots, not only for one country but for the planet" (Participant from the 1st workshop). **Environmental concerns in robotics primarily point to the amount of CO_2 produced by robots and the environmental impact of the international shipping of robot parts.** More specific regulations are also needed in this area according to the findings.

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4. Solutions and Resources

4.1. Positive Future Scenarios

Future scenarios largely depend on the way the newly adopted legal regulations, such as the EU AI Act and the new General Product Safety Directive (GPSD), are implemented in real-life production settings. The EU AI Act puts great emphasis on securing human supervision and control over AI applications, which also encompass AI-based industrial robotics, while the GPSD sets more precise requirements for product safety standards and consumer awareness. While these regulations address the ethical issues regarding the need to preserve human autonomy in human-robot interactions by opting for regulations to secure human supervision, the above findings also underline the importance of accounting for data and social issues emerging from said human-robot interactions.

Once these issues are accounted for, a potential positive scenario for robotics in agile production is one in which robots' implementation is done through participative processes involving workers. Maintaining the human at the centre, robotics solutions for agile production can be developed and implemented in a way that ensures the protection of workers, trust and social acceptability. Considering context-specific needs by also consulting with workers' and worker organisations is fundamental to ensure a meaningful introduction of robotics for agile production.

4.2. Key Initiatives and Organisations

SPARC Robotics Initiative (2014 - 2020)

SPARC Robotics initiative is a European public-private partnership (PPP) on robotics and the largest civilian-funded robotics innovation program in the world. It brings together the European Commission, and European industry and academia to facilitate the growth and empowerment of the robotics industry and value chain, from research through to production. SPARC's members range from manufacturing and production to healthcare and agriculture. Within their areas of interest, there is also agile production which is part of the Digitising European Industry initiative and on which SPARC incentivised community building and knowledge making. In addition, SPARC's efforts on upskilling and reskilling workers are very relevant to the area of agile production where job loss is a persistent fear.

euRobotics

EuRobotics is a Brussels based international non-profit association for all stakeholders in European robotics. It was founded in September 2012. EuRobotics includes a topic group on Industrial Robotics and one on Logistics and Transport which aim to facilitate the adoption of robotics in areas relevant to agile production. Their areas of interest include materials manipulation, materials handling inside manufacturing facilities, smart supply chain management, automation of hazardous tasks and integrated systems. The groups bring together experts and policy makers to address the environmental, political, legal and ethical issues to the adoption of robotics in manufacturing plants and for logistics management.

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International Federation of Robotics (IFR)

This federation was established as a non-profit organisation in 1987 to connect the robotics community around the world. The IFR aim and purpose is to promote the positive benefits of robotics, promote research, development, use and international co-operation in the field of robotics, and to act as a focal point for organisations and governmental representatives in activities related to robotics. IFR brings together over 90 members from 20 countries and provides useful resources, case studies and statistics on the topic of robotics. For example, every year IFR conducts a study on World Industrial Robotics including national data and statistics on robot use and degree of automation which are useful resources for data and comparison between countries.

The APRIL project (Horizon 2020, 2020-2024)

The APRIL project (multipurpose robotics for mAniPulation of defoRmable materIaLs in manufacturing processes) is developing autonomous, dexterous and market-oriented robot prototypes to innovate the manufacturing of flexible and deformable materials in European enterprises. Materials manipulation is one of the tasks which robots in agile production can undertake, which is testified by the large number of robots for welding existing. The project is funded under the Horizon 2020 research grants and will be concluded in spring 2024.

The CONVERGING project (Horizon Europe, 2022 - 2026)

CONVERGING aims to develop, deploy, validate, and promote smart and reconfigurable production systems including multiple autonomous agents (collaborative robots, AGVs, humans) that are able to act in diverse production environments. Through its activities, CONVERGING promotes the transition to agile production. The project has received funding from the European Union's Horizon Europe Research & Innovation Programme, it started in 2022 and will end in 2026.

DIH^2 (Horizon 2020, 2019 - 2023)

DIH^2 makes use of DIH^2 Network and the B2B platform RAMP (Robotics and Automation Marketplace) to endow manufacturing companies necessary services and equipment to develop and implement an agile manufacturing strategy. The project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 824964.

Fraunhofer Institute for Manufacturing Engineering and Automation (IPA)

The Fraunhofer Institute for Manufacturing Engineering and Automation (IPA) is a Stuttgart-based research institution that has made significant contributions to robotics solutions in agile manufacturing. As a part of Cyber Valley, the AI Innovation Center "Learning Systems" operated by Fraunhofer IAO and Fraunhofer IPA supports companies in their trajectory to adopt AI solutions in their production processes. Fraunhofer IPA develops automation solutions for a variety of sectors, including manufacturing, by using cognitive robotics.

OpenMOS (Horizon 2020, 2015-2019)

Open dynamic Manufacturing Operating System for Smart Plug-and-Produce Automation Components (OpenMos) is an EU project introduced to facilitate the transformation towards agile solutions in the manufacturing sector through increased automation. The project envisaged developing an open-source P&P system to enable all stakeholders in the automation system value chain to work on a common platform. This system smoothly integrates machines and automation systems within the manufacturing ecosystem.

Trinity (Horizon 2020, 2019-2022)

Trinity is an EU project which envisages the development of a Robotics Innovation Hub composed of research centres, universities and companies to work on a wide variety of topics focused on agile production. The main themes of the project include advanced robotics, digital tools and platforms, and Cyber-Security technologies, considered to be the main drivers for a wider uptake of advanced robotics systems. They have identified "collaborative robotics including sensory systems to ensure safety, effective user interfaces based on augmented reality and speech, reconfigurable robot work cells and peripheral equipment (fixtures, jigs, grippers...), programming by demonstration, Internet of Things (IoT)" (Lanz et al., 2021) as the recent robotics trends in agile production. The TRINITY network has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 825196 and operated between 2019 and 2022.

4.3. Relevant Regulations

Occupational Safety and Health Administration (OSHA)

While OSHA doesn't have any specific standards for the robotics industry, it provides guidelines for recognizing hazards related to robotics in the workplace.

International Electrotechnical Commission (IEC)

The IEC has published a standard, IEC 80601-2-77, to address the specific performance and safety characteristics of robotically assisted equipment used in surgery. The standard is expected to be adopted in the near future by regulatory authorities in most international medical markets for use in assessing the safety of advanced robotic systems and devices used in surgery.

The General Data Protection Regulation (GDPR)

The GDPR, regulating the use of personal data, is relevant for the robotics industry in agile production, as cobots can collect personal data. Yet, GDPR only partly regulates AI systems, having rules on processing personal data and protecting data subjects against merely automated decision-making[4].

[4] J. Meszaros, J. Minari, I. Huys, "The future regulation of artificial intelligence systems in healthcare services and medical research in the European Union," Front. Genet, 13: 927721, October 2022.

International Organization for Standardization (ISO)

ISO/TS 15066:2016 is a technical specification which provides safety requirements for collaborative industrial robot systems and the work environment. It supplements the requirements and guidance on collaborative industrial robot operation given in ISO 10218 and ISO 10216-2.

The EU Artificial Intelligence Act

The newly adopted EU AI Act will have great importance for the production sector. This new regulation introduces a risk-based approach to AI systems based on the principles of ethical AI. It foregrounds human supervision over AI systems and takes measures to protect human autonomy, dignity and safety. The future impact of this regulation on the production robotics system is yet to be studied.

The EU General Product Safety Regulation (GPSR)

The General Product Safety Regulation (GPSR) will replace the current General Product Safety Directive as of 13 December 2024. This new regulation modernises the EU general product safety framework, particularly addressing the new challenges posed to product safety by digitization processes. In the context of robotics, it provides precise requirements for product safety, also in connection with data privacy and protection.

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5. Conclusions

In a time when Industry 4.0 has given way to Industry 5.0 and beyond, automation solutions powered by AI-based robotics are getting more and more autonomous, endowed with tactile and haptic qualities. In this environment, the growing need for collaborative robots in the automation industry drives the manufacturing sector. During this transformation, it is of utmost importance to adapt a sociotechnical approach to the integration of collaborative robots in agile production that would foreground societal needs and democratic values.

The above-mentioned five pillars of analysis, including socioeconomic, ethical, legal, data-related and education and engagement-related considerations, provide the audience with a wide framework to better grasp non-technical challenges to the wider uptake of robotics solutions in today's manufacturing industry. While both real and perceived safety threats posed by collaborative robots in the workplace continue to be the main ethical obstacles to the wider adoption of these solutions, there is a growing need to develop safety guidelines which would not rely on restricting the speed and force applied by robots. Fears around job replacement and skills depreciation continue to be significant socio -economic obstacles to the wider uptake of cobots in the manufacturing industry. Negative perceptions around issues related to data privacy, data protection and cybersecurity are also prevalent in the sector. The lack of safety standards and regulations suitable to respond to the shift towards collaborative robots also stands out as a significant legal challenge to be addressed.

In this picture, education and engagement activities need to be developed to better inform both the public and workers and trade unions regarding real-life safety levels of cobots. It is also important to conduct training and engagement events to address common fears around job replacement and skills depreciation. Data issues need to be adequately addressed in these activities. For this purpose, Robotics4EU has been conducting a series of workshops with the aim of educating and engaging with stakeholders in the agile production sector regarding these non-technical drivers with the aim of achieving a more socially responsible uptake of robotics solutions within the agile production ecosystem.

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