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Collaborative robots, human-AI systems and the role for policy

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Background

This Policy Brief has been developed in the framework of the Advanced Technologies for Industry (ATI) project, initiated by the European Commission's Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW), and the European Innovation Council and Small and Medium-sized Enterprises Executive Agency (EISMEA). Policy Briefs analyse national and regional policy measures focused on a specific challenge, technological area or mode of implementation, and they explore policy tools designed and implemented with the aim of fostering the generation and uptake of advanced technologies. The reports provide a comparative analysis and bring examples of relevant national and regional policy measures in the EU.

This report focuses on analysing the consequences of artificial intelligence (AI) and robotics-based automation on industry and work, the related human-machine systems and human-computer interaction, and the need for policy to support a positive transition and mitigate the potential risks.

Automation (mechanical or virtual) is a process or task performed by software or a machine. Automation comes in many shapes and differs with respect to its degree of flexibility and the functional autonomy with which it performs a single task or a variety of tasks. Industrial automation uses robots and other automated tools in different industrial settings (e.g. 3D printing, machines for hazardous environments). Business process automation is in charge of basic non-manufacturing activities (i.e. software tools for human resources, accounts and contract management). Robotic process automation is used in higher-level automation, where software is used in certain circumstances to augment process performance and carry out complex tasks.

As highlighted by the Harvard Business Review (2020), companies that automate their operations will see productivity gains only if they put in place mechanisms to enhance collaborative intelligence. Humans, AI and machines thus need to work together, which demands better understanding of how these new systems operate and better skills to manage them.

The Covid-19 pandemic has spurred interest in digital industrial operations and business models. Workers and employees were forced to rely on digital tools and interact with machines much more than before the crisis.

In this context, the specific objectives of this analysis have been to:

- Discuss current trends in human-machine collaboration and map the different challenges related to these new complex systems
- Identify policy approaches and measures deployed to foster a beneficial shift towards human-controlled automation and mitigate the related risks
- Explore any policy gaps in support of technological transformation and provide inspiration for policy action

The report is made up of three parts. The first section identifies the key policy challenges. The second section analyses policy responses, strategies and policy initiatives at EU and national levels. The third section offers a summary of the findings and policy considerations.

This study is based on a comprehensive literature review, interviews and expert assessment.

Section 1

1. Impact of automation on industry and the workplace

Key messages

Artificial intelligence, or AI as it is widely known, robotics and other related advanced technologies are undoubtedly transforming our industries. Collaborative robots and AI will play an important role in increasing industrial competitiveness as they enable manufacturers to produce better products in a safer setting, and to do so more cost-effectively.

A wide range of studies have tried to predict to what extent industrial automation would replace jobs and have an impact on employment in general. Some more **recent research now suggests more optimistic outcomes in favour of job creation**. Although the exact long-term affects cannot be fully foreseen, currently there are no substantial negative effects on occupations observed, according to the latest evidence. Human-machine systems can actually create new opportunities that increase the demand for new forms of skilled professionals.

Besides the impact of AI and robotics on jobs, the work-related and broader societal effects should also be considered. Human-robot and human-AI interactions can have a negative impact on human relationships and affect worker safety, but they can also create psychosocial stress. Change management and organisational innovation that can address these impacts will be key to motivating people to adopt a new mindset and behaviour regarding these digital developments.

Policy actors will need to run more foresight exercises to better assess the repercussions of how AI and robotics can be integrated into the workflow. Policymakers will need to tackle questions around **occupational safety, health, liability and ethics**. They will also need to incentivise quality aspects through better **data collection and data management**.

Policy debates should not only discuss AI and robotics from a technological perspective but also how collaborative and intelligent systems can be created that address industrial as well as broader societal goals that combine the power of humans and machines working together to create new 'human value'.

1.1 Human-robot and human-AI systems for higher industrial competitiveness

Artificial intelligence, robotics and other related advanced technologies are transforming all sectors of the economy and have a profound impact on industry, the workplace and on our society. The analysis of the ATI business survey[1] highlighted that while robotics technologies were initially deployed in manufacturing, new applications are emerging, and multiple novel use cases proliferate. Robotics is used for a wide variety of tasks, from shop floor production automation to warehouse inventory management, but it also has great potential in the healthcare sector. AI-related applications also encompass today a mix of horizontal solutions and industry-specific scenarios.

In our current context, attention is often put on the technology, on the robotic application or AI-software, while the importance of the human component is less prominent. Putting aside all the futuristic scenarios and looking at the actual practice, robotics and algorithms cannot fully operate without a human agent guiding and interpreting these new digital/electronic tools. Instead, there is a need to think in terms of human-machine or human-computer systems where the two collaborate.

Box 1: Cobots (collaborative robots) in practice

Collaborative robots equipped with a vision camera enable the sub-assembly of automotive engines. They can support the inspection of components and increase the accuracy of outcomes where manual inspection is subject to errors. The robot operates next to employees on the line and creates a human-machine system, increasing efficiency and quality control.

Source: https://www.universal-robots.com/case-stories/comprehensive-logistics/ picture from Freepik

[1] please see ATI Watch on 'Technology focus on artificial intelligence' available at https://ati.ec.europa.eu/reports/technology-watch/technology-focus-artificial-intelligence

In the factory, **collaborative robots play an increasingly important role** and enable manufacturers to produce more cost-effectively. '**Cobotics**' involves direct collaboration between workers and robots in a shared space, where human capabilities are significantly enhanced by advanced machines. Applications include remote collaboration, co-manipulation, or the worker wearing an exoskeleton that increases his or her power, stamina or performance. In this new interaction, while the machine is doing the repetitive tasks, the worker can focus on problem-solving. Cobots can be used for various tasks such as waste-sorting, picking, heavy-lifting, loading, dirty or dangerous tasks. For instance, Amazon has more than 200 000 mobile cobots working in its warehouse network that help speed up delivery.

In the area of cobotics, the latest technological developments concern mostly vision and sensor systems and how they increase precision and flexibility in given tasks. The effectiveness of sensing technologies is crucial for worker safety as well. They can assess if a person is getting too close[2] to a dangerous operation or activity.

In a similar way, human-computer interaction is the backbone of successful AI transformation projects. AI systems can play a beneficial role also in addressing the Covid-19 pandemic, for instance by modelling infection dynamics and socio-economic impact, monitoring physical distancing and supporting the development of vaccines[3].

Artificial intelligence is based on data selected and compiled by people. In many current applications, AI is only useful if accompanied and interpreted by a human who understands how it operates and how to deal with the results. For example, machine-learning can be effectively used for streetlight automation planning. Nevertheless, human experts are needed to make decisions in certain contexts[4], and human–AI interaction leads to much better overall outcomes than letting machine-learning models operate on their own.

An important question for the future is how we can create interactive intelligent systems that address our key societal goals and combine the power of humans and machines to create new value.

1.2 Impact of automation on work

The rise of AI and/or robotics in automated factory operations and business processes has created a lot of debate around the impact of automation on jobs. With the seminal work of Frey and Osborne (2013), many studies have cautioned that a range of jobs could potentially disappear or diminish in relevance as a result of technological transformation.

In the work of Smids, et al. (2020), the authors provide several examples of how robotisation can affect the work environment. The possible opportunities or threats of introducing robots in the workplace are summarised in Table 1.

Although automation has already replaced many human tasks (especially in finance) and will displace many other jobs over the coming years, it is also generating demand for different skills or changing the nature of tasks. An OECD (2018)[5] study on automation, skills use and training reveals that about 14% (66 million workers) of jobs in OECD countries are at high risk of replacement due to automation, while 32% of jobs have a 70%-plus risk of changing. The median job in the study has a 48% chance of being partly automated. Jobs of junior-level workers are at the highest risk of automation, followed by senior-level workers.

Table 1: Opportunities and threats of robots

Work aspects	Threat	Opportunity
Pursuing a purpose	If robots take over many or the most challenging tasks of a job, workers may experience less purposiveness.	If robots take over the most tedious or boring task, or if teaming up with robots helps to better pursue a worthy cause, workers might have an enhanced sense of purposiveness.
Social relationships	If human co-workers are replaced by robots, social interaction is reduced, and its nature will change.	If future robots are designed as colleagues, capable of high-level social interaction, the need for relatedness may still be fulfilled. If robots take over repetitious tasks, more time is left for interpersonal contact.
Exercising skills and self-development	Tasks taken over by robots make corresponding human skills obsolete.	Humans often need to maintain the relevant skills and need new complex skills to operate robot technology
Self-esteem and recognition	If robots take over the most difficult tasks, social recognition and self-esteem may be diminished.	Teaming up with robots may lead to expanding skills and better outcomes, leading to greater social recognition and higher self-esteem.
Autonomy	Robot control deprives human workers from exercising judgment and autonomous agency. Little opportunity for job crafting. Ethical worries related to surveillance and AI opacity.	Human workers control robots and enhance their capacities for autonomous agency. More room for job crafting.

Source: Smids, et al.(2020)

A recent Cedefop analysis (2020) concludes that there is no need to paint a bleak picture of the impact of automation. The study findings show that five years on from the predictions of Frey and Osborne (2013), **there has been little evidence of substantial negative effects on the occupations highlighted as fully**

[2] https://www.theengineer.co.uk/technical-qa-cobotics/
[3] IEEE (2020) Statement Regarding the Ethical Implementation of Artificial Intelligence Systems (AIS) for Addressing the COVID-19 Pandemic
[4] Nascimento et al. (2018)
[5] https://www.oecd-ilibrary.org/employment/automation-skills-use-and-training_2e2f4eea-en;jsessionid=WkhPit5ivkJFuu68Dv1ee-4E.ip-10-240-5-122

automatable. They drew attention to the importance of careful monitoring but also warn against a 'technological alarmism' (McGuinness et al., 2019), in the absence of strong evidence of negative effects. Similarly, a McKinsey study argues that **the adoption of AI might not have the substantial effect on net employment that many feared**. According to the average global scenario *"total full-time-equivalent-employment demand might remain flat, or even that there could be a slightly negative net impact on jobs by 2030"*[6].

It should be noted that automation generally does not affect entire jobs but specific tasks (see Table 3). AI plays a supportive role, empowering or helping humans to perform better in handling complex and critical situations that require judgement and creative thinking. AI-driven demand is expected to rise for the following types of jobs[7, 8]:

- Developers of new AI technologies (e.g. software and application developers, robotics engineers, AI and machine-learning specialists)
- Jobs engaging with AI technologies (e.g. data analysts and scientists, e-commerce and social media specialists)
- Roles for supervising AI technologies (process automation experts, information security analysts)
- Roles leveraging human skills and facilitating societal shifts that accompany new technologies (e.g. customer service workers, sales and marketing professionals, training and development, organisational development specialists, innovation managers)

Table 2: Examples of tasks and sectors impacted by AI and cobots

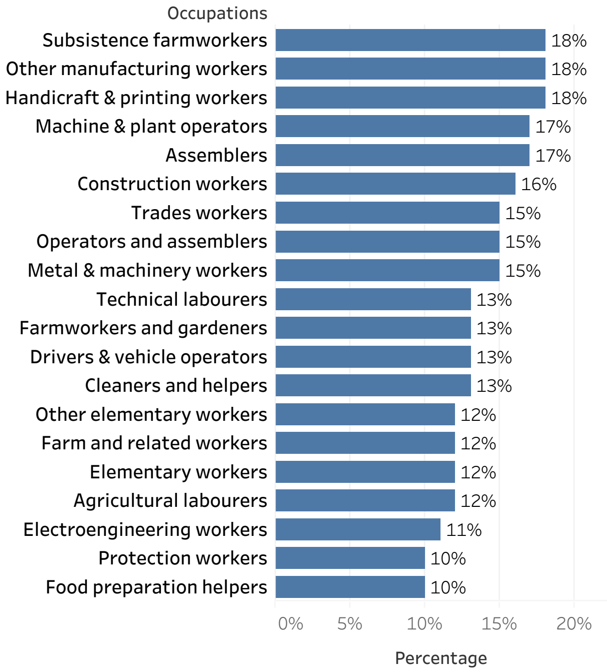
Tasks	Sectors
Data management	Professional services, healthcare (e-health)
Procurement management, data processing, information retrieval	Government, industry
Accounting	Financial services
Telemarketing	Professional services, telecom and media
Radiology	Healthcare
Administration	Healthcare (patient administration)
Harvesting	Agriculture
Assembly	Automotive, manufacturing
Waste collection	Utilities, manufacturing

Source: Technopolis Group

Although tasks that address clear objectives and complete predictable actions are more suitable for machine-learning, it does not mean that all tasks requiring emotional intelligence and creativity will be out of AI's reach, as can be seen in industrial design or customer-service chatbots. When AI-systems and machine-learning become more cost-effective than humans on a task, profit-maximising managers may increasingly seek to automate such tasks, with a view to increasing productivity and lowering prices, with an effect on the overall economy, shifting labour demand and restructuring organisations and sectors[9]. AI could increase labour productivity by up to 40% by 2035 in developed countries compared to expected baseline levels[10].

Different countries and industry sectors will feel the impact of 'job automatability' more than others. For example, jobs in Anglo-Saxon, Nordic countries and the Netherlands are expected to be less affected than those in eastern and southern European countries[11]. The financial sector is expected to be largely impacted (e.g. financial services where algorithms can lead to faster and more efficient analysis), while the health sector may be relatively less impacted due to a greater reliance on social skills and the need for human involvement[12].

Table 3: Shares of employees in EU27 with high automation risk in 2020 (occupations with a higher risk than 10%), based on Cedefop



Source: Cedefop, Skills Panorama available at https://skillspanorama.cedefop.europa.eu/en/dashboard/automation-risk-occupations#2

[6] https://www.mckinsey.com/featured-insights/artificial-intelligence/notes-from-the-ai-frontier-modeling-the-impact-of-ai-on-the-world-economy
[7] Caruso, L. (2018)
[8] World Economic Forum. (2018)
[9] Ibid
[10] OECD (2019). Artificial Intelligence in Society
[11] OECD (2020)
[12] https://www.pwc.co.uk/services/economics/insights/the-impact-of-automation-on-jobs.html

1.3 Skills challenge

To reap the full benefits of automation, AI and robotics, businesses will need to make substantial organisational changes. At the same time, they will have to address skill shifts and provide continuous learning options. The introduction of automation means human resources staff need to be prepared; resource planning, recruitment, selection and retention, learning and development, remuneration and benefits systems and career planning functions[13]. In addition, they may need to adapt organisation structures, work processes and systems.

Research conducted by McKinsey suggests that the need for advanced technological skills (e.g. programming) is expected to grow rapidly, as well as social, emotional and higher cognitive skills, such as creativity, critical thinking and complex information processing. By 2030, demand for social and emotional skills is expected to grow across all industries by 22% in Europe, while demand for entrepreneurship and initiative taking will rise by 32%. However, demand for physical and manual skills, as expected, will decline (11-16% overall) but still remain the biggest category of workforce skills in many countries in the coming decade[14]. For instance, basic data-input and processing skills will drop by 19-23% for all sectors for the same period, as machines increasingly take over data-entry tasks[15].

The World Economic Forum predicts that nearly 50% of all employees will require significant reskilling and upskilling in the coming years[16]. It is estimated that 35% of workers will need to obtain additional training of up to six months, 9% will require reskilling lasting between six and 12 months, while 10% are expected to require additional training of more than a year. Two-thirds (66%) of respondents to a McKinsey study listed their top-ten priority is to address automation-related skills gaps (see Figure 2)[17].

The Global Human Capital Trends survey (2021) reveals significant future demand for human skills, such as **complex problem-solving (63%), cognitive abilities (55%), social skills (52%) and process skills (54%)**. A shortage of technical skills is another major concern for over 60% of respondents.

Businesses are adopting different strategies to address the growing shift in skills demanded thanks to automation and AI. For instance, some companies are hiring new temporary staff with relevant skills in new technologies, while others are fully automating specific work tasks and expect that employees will 'upskill' on the job or in their own time.

The Covid-19 pandemic has demonstrated a more urgent need for reskilling and upskilling. Covid-19 sped up the adoption of fully digitised approaches such as in-person learning through live video and social sharing. To make sure that organisations thrive after the pandemic, new strategies are needed to consolidate this progress[18]. With employee engagement levels on the decline during the crisis – and the corresponding impact on morale, wellbeing and productivity – supporting personal growth is going to be a key driver of overall engagement and thus better performance.

1.4 Key policy challenges

Human-robot and human-AI systems are expected to play a key role in the future of work. In order to avoid conflicts between robots and humans, the rules of interaction should be clearly defined. Beyond the clear benefits to perform dangerous tasks or process big data, these technologies can potentially undermine occupational safety and the health of workers. Flexibility, reliability and autonomy allowed in cobotics remain a challenge[19]. The environment ideally fitted for a robot is usually different than a workplace better suited to human workers[20].

Weiss et al. offer a theoretical and methodological framework for managing digital transformation within organisations, including task allocation and reskilling, to ensure that automation benefits both employers and employees, and is thus accepted by the workforce. USUS models developed by the authors help to evaluate human-robot collaboration considering usability, social acceptance, user experience and societal impact[21]. Such models and decision-making support can also mitigate the negative impacts on workers' conditions and well-being.

Successful technological transformation which harnesses the power of human-robot/AI interactions faces various challenges that can be addressed both by policy and change in industrial behaviour. Key challenges include:

- Data and technology
- Qualifications and skills
- Change management and organisation
- Safety and occupational health
- Liability
- Ethical behaviour

[13] Nankervis, A. et al. (2019)
[14] McKinsey (2018)
[15] Ibid
[16] WEF (2018) Future of Jobs
[17] McKinsey (2020)
[18] McKinsey, 2020
[19] See also Pauliková, A.; Gyurák Babeľová, Z.; Ubárová, M. (2021). Analysis of the Impact of Human-Cobot Collaborative Manufacturing Implementation on the Occupational Health and Safety and the Quality Requirements
[20] Royakkers, L., & van Est, R. (2015). A literature review on new robotics: automation from love to war. International journal of social robotics, 7(5), 549-570
[21] Weiss, A., Bernhaupt, R., Lankes, M., and Tscheligi, M. (2009). The USUS evaluation framework for human-robot interaction

Collaborative robotics and AI as part of Industry 5.0 strategies

Numerous examples and use cases demonstrate the positive impact of using AI and machines to augment human capabilities. Despite this, the uptake of robotics is still low. According to the latest Eurostat statistics (2020), 5% of enterprises used industrial robots in the EU27. The ATI business survey found that 24% of organisations in the sample used robotics technology (broadly defined) in 2020. There is also still much to do not just to foster more adoption but also to encourage the responsible use of robotics and AI across industries. In this sense, the thinking in collaborative robotics and AI should be integrated into the Industry 5.0 discussions.

Industry 5.0 reflects the shift towards making industries more future-proof, resilient, sustainable and human-centred. It is understood as a forward-looking exercise by looking at emerging societal trends and developing innovative technologies in a human-centric way. Industry 5.0 is about empowering employees and opening up new horizons by working with advanced technologies.

Related to the shift to Industry 5.0 models, governance structures will need to be adjusted as well. Collaborative AI and robotics not only concern industry; they also have an important impact on employees, citizens and our society as a whole. Future employees will need to be involved in the design of AI technologies or robotics solutions in order to limit and control any potential bias, misfit or discrimination. The modalities of governance will need to be elaborated; how a broader set of stakeholders can participate in aspects such as data management, technology design and the actual use case. In this sense, a human-centred design approach needs to be part of the process.

Managing trustworthy data

AI and robotics-based automation relies on large volumes of data. The quality of the original datasets are crucial to ensure that these new systems operate effectively. Data should also be balanced against privacy, transparency, accessibility and security. This in turn needs adequate data protection practices, data management, safe data sharing and cybersecurity measures.

Liability

The use of collaborative robots and AI systems raises legal issues around liability and responsibility which need to be considered. It should be clarified who is legally responsible to pay for losses or compensation in the event of mishaps. The regulatory framework needs to fit human-machine systems and new ways of working.

The reasons behind an AI-based system's errors are difficult to verify since they continuously learn and their new decisions cannot always be traced back. Failures can be related both to the programmer feeding AI with biased training data but also failures in terms of cybersecurity[22].

Skills needs beyond technology

The skills challenge has already been highlighted above, but its policy implications have to be reiterated. To meet the requirements of human-machine systems, industry will need more workers with specialised skills on how to interact with robots. As AI and robotics are introduced in workplaces, they lead to a change in the mix of occupations as well as skills and educational requirements. To ensure the effectiveness of humans working alongside machines, the work will need to be redesigned and retooled. Several skills including technological as well as social and emotional capabilities will increase, while demand for physical and manual skills is expected to drop[23]. Firms will need to put in place new types of training programmes that balance motivational aspects (sense of purpose) with overall efficiency gains from robotisation of industrial production[24].

Enhancing the skills of women and increasing their participation in AI/robotics development should be a priority to reduce gender bias. The World Economic Forum's Global Gender Gap Report conducted in 2019 showed that only 22% of AI professionals are female, which can have a huge impact on the design of algorithms.

Impact on health and safety

The potential negative consequences of AI and robotics applications are manifold including stress, discrimination, musculoskeletal disorders, but also the possibilities of work intensification and psychosocial risks. AI can amplify various occupational safety and health risks, although it is not the technology itself but the way human-AI/robotics interactions are set up and implemented that cause negative or positive consequences[25]. There is also much work still needed to develop optimal ergonomics in terms of the physical constraints on operators (e.g. in using exoskeletons). There are also potential negative consequences on mental health.

The EU-OSHA report, 'Foresight on new and emerging occupational safety and health risks associated with digitalisation by 2025', identifies

[22] European Parliament, 2019
[23] https://www.mckinsey.com/featured-insights/future-of-work/ai-automation-and-the-future-of-work-ten-things-to-solve-for
[24] Pauliková, A. et al. (2021) Analysis of the Impact of Human–Cobot Collaborative Manufacturing Implementation on the Occupational Health and Safety and the Quality Requirements
[25] https://osha.europa.eu/en/publications/osh-and-future-work-benefits-and-risks-artificial-intelligence-tools-workplaces

the following associated risks and challenges for occupational health and safety[26]:

- The potential for automation to remove humans from hazardous environments, but also to introduce new risks, particularly influenced by the transparency of the underlying algorithms and by human-machine interfaces.
- Psychosocial and organisational factors that will become increasingly more important because ICT-enabled technologies can drive changes in the types of work available; the pace of work; how, where and when it is done; and how it is managed and overseen.
- Increasing work-related stress, particularly as a result of the impact of increased worker monitoring made possible by advances in and the increasing presence of wearable technologies, 24/7 availability, blurred boundaries between work and private life, and the online platform economy.
- Risks associated with new human-machine interfaces, in particular related to ergonomics and cognitive load.
- Cybersecurity risks due to increased interconnectedness between things and people.

Collaboration between academics, industry, social partners and governments on research and innovation will be key in the development of technologies to properly take account of the human aspects.

Ethics

Ethical behaviour will be important to ensuring that our society as a whole can mitigate the negative consequences of AI including bias or discrimination. It is important that technology designers take more responsibility, guided by law and policy initiatives, and act in an ethical and responsible way. Human-computer interaction needs to be repurposed to engage with legal and regulatory aspects of a system including participatory design[27]. For instance, AI algorithms can be effectively applied in human resources management and in the recruitment of new staff. Nevertheless, built-in biases can create issues such as favouring a certain race, gender or characteristics. As a result, the actual decisions taken might exclude certain groups of people from the labour market, moreover lead to less innovation (if real talent is not recognised). Training data that includes information about a broad group of candidates are essential. AI algorithms should be carefully trained and the decision-maker fully acquainted with how AI actually works.

[26] EU-OSHA. (2018). Foresight on new and emerging occupational safety and health risks associated with digitalisation by 2025, Luxembourg: Publications Office of the European Union. Retrieved June, 2020 from osha.europa.eu: https://osha.europa.eu/en/tools-and-publications/publications/foresight-new-and-emerging-occupational-safety-and-health-risks/view

[27] Urquhart and Rodden (2016)

Section 2

2. Policy measures and initiatives

Key messages

At national level, various EU Member States have an AI strategy and programmes to foster technological development including robotics or the uptake of cobotics solutions. There are **only a few examples where policy measures are in place to tackle the related risks, incentivise ethical behaviour and systematically monitor the impact of human-machine systems on work**. Initiatives focus much more on the technological challenge and less on the organisational and ethical aspects that such transformation and new collaborative AI or robotics will require. Despite national AI strategies launched in most countries, few of them discuss the implications of AI on ethical behaviour and with regard to the labour market. Nevertheless, we find various research projects financed at national level that aim at assessing the longer-term impact of robotics or AI.

The **European Union has been particularly active in setting new requirements towards AI technology-based solutions**. More needs to be done in terms of integrated thinking where AI and robotics are not regarded separately but in the context of human-machine systems where technology, human intelligence and creativity work together in harmony.

2.1 European policy framework

Research and innovation policies across Europe actively promote the development of AI and robotics technologies. Yet, the understanding of how workers and robots, employees and AI software can function alongside one another is still at an early stage. Beyond unleashing the potential in these technologies, policy will need to foster a positive technological transformation and, at the same time, play an important role in mitigating the less beneficial (and potentially harmful) societal (or even health) consequences of automation and human-machine interactions. This section brings policy examples from international, European and national levels.

Human wisdom is being challenged on a range of issues that AI raises today, including privacy, fairness, safety, democracy and sustainability.

The European Union has been particularly active in setting new requirements towards AI-based technologies and solutions. Most recently, in April 2021, the European Commission launched a proposal for a regulation laying down harmonised rules on AI[28]. The objective is to turn Europe into the global hub for trustworthy AI. The proposal strives to balance the numerous risks and benefits

Figure 1: Whitepaper on AI – key points

Source: European Commission, 2020

[28] Please see https://ec.europa.eu/commission/presscorner/detail/en/ip_21_1682

the use of AI can provide. The Regulation on AI pursues four objectives:

- To ensure that AI systems placed on the EU market are safe and in line with existing EU law on fundamental rights and values;
- To ensure legal certainty when facilitating investment in and innovation into AI;
- To enhance governance and effective enforcement of the existing law on fundamental rights and safety requirements applicable to AI systems;
- To facilitate the development of a single market for lawful, safe and trustworthy AI applications and to prevent market fragmentation.

The history of AI legislation goes back to 2018, when under the supervision of Mariya Gabriel, former Commissioner for Digital Economy and Society, the High-Level Expert Group on Artificial Intelligence (AI HLEG) was created to support the implementation of a European approach to AI and robotics. This included the elaboration of recommendations on future-oriented policy development and on ethical, legal and societal issues related to AI, including socio-economic challenges.

The Guidelines propose seven key requirements that AI systems should meet in order to be trustworthy: human agency and oversight, technical robustness and safety, privacy and data governance, transparency, diversity, non-discrimination and fairness, societal and environmental well-being and accountability. For each of these key requirements, a practical implementation guide has been produced.

The second deliverable includes 33 practical recommendations on how to empower and protect humans and society in the AI era, while creating multi-stakeholder alliances, which offer a tailored approach to capturing new technological opportunities in the Single European Market.

The European Commission published a **White Paper and a Report on the safety and liability aspects of AI**[29] in February 2020. The White Paper includes guidelines on **how to adopt a human-centred approach to AI**, recognising that trust needs to be built in order for society to take up AI applications. It also highlights the potential risks of certain AI applications and the need to uphold the principles of non-discrimination, fairness and transparency. Privacy, safety, human oversight, well-being and accountability will need to be respected.

Also relevant for the ethical perspective is a report published in 2019 by the EU Agency for Fundamental Rights on Data Quality and Artificial Intelligence on mitigating bias and error to protect fundamental rights. The report stresses the importance of being aware of the flaws of data used to train AI algorithms and to mitigate potential biases, including gender bias, that undermine the principle of non-discrimination.

Standardisation of robotics

The European Parliament adopted a resolution on 16 February 2017 with recommendations to the Commission on civil law rules on robotics. The main assumptions are the human right to privacy, respect for human frailty, transparency in the programming of robotic systems, and the need for predictability of robotic behaviour. The resolution clarifies the definition of 'smart autonomous robots' and recommends an ethical framework.

The International Organisation for Standardisation (ISO), serving as the worldwide federation of national standards organisations, prepares standards concerning robots through the ISO Technical Committee 299 with the title 'Robotics'. It provides respectively guidelines for the design and implementation of a collaborative workspace that reduces risks to people, and it provides a foundation for work in this area, since we expect to learn more as applications are deployed and technology develops.

It specifies the definitions, important characteristics of safety control systems, factors to be considered in the design of collaborative robot systems, built-in safety-related systems and their effective use and guidance on implementing the following collaborative techniques: safety-rated monitored stop; hand guiding; speed and separation monitoring; power and force limiting.

Standardisation of AI

The professional association Institute of Electrical and Electronics Engineers (IEEE) has launched a proposal aimed at technology experts and researchers to issue new standards for AI, particularly by investigating and focusing on ethics-related issues of autonomous and intelligent systems. More specifically, 13 committees have been created to cluster insights from technical and sociological experts from academia, industry, civil society, policy and governments. The 'Ethically Aligned Design'[30]

[29] https://ec.europa.eu/info/sites/default/files/commission-white-paper-artificial-intelligence-feb2020_en.pdf

[30] https://standards.ieee.org/content/dam/ieee-standards/standards/web/documents/other/ead_v2.pdf

includes concrete recommendations on "*how to establish ethical and social implementations for intelligent and autonomous systems and technologies, aligning them to defined values and ethical principles that prioritise human well-being in a given cultural context.*".

In 2020, ISO and International Electrotechnical Commission (IEC) jointly established a standardisation committee on AI (the ISO/IEC JTC 1/SC 42), with the aim of setting internationally recognised common standards in the fields of big data (particularly by agreeing on definitions and architecture requirements) and AI (particularly by investigating trustworthiness).

2.2 National policies

At national level, various EU Member States have an AI strategy and programmes to foster technological development including robotics or the uptake of cobotics solutions. There are only a few examples where policy measures are in place to tackle the related risks, incentivise ethical behaviour and systematically monitor the impact of human-machine systems on work. Among the examples identified, several Member States (e.g. Denmark, Finland, France, Germany, the Netherlands) have a programme to foster skills development and adjust training and education to the new needs of the future workplace. Despite national AI strategies launched in most EU countries, few of them discuss the implications of AI on ethical behaviour and with regard to the labour market. Nevertheless, we find various nationally funded research projects assessing the longer-term impact of robotics or AI.

Ethical considerations of human-robot/AI systems and how they will influence work, safety or society are often embedded in research projects conducted within innovation ecosystems and clusters driving robotics or AI developments.

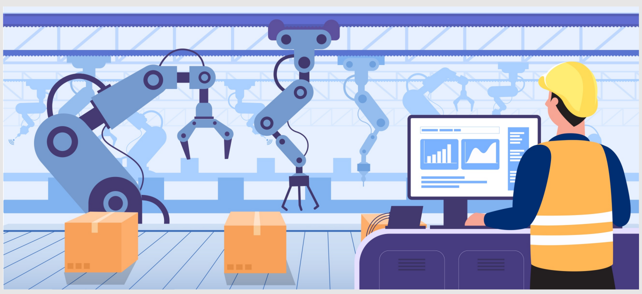
Skills development in Denmark, Ireland and the Netherlands

In **Denmark**, the Odense Robotics, RoboCluster and UAS Denmark joined forces in 2021 and now cover different parts of the robotics value chain, integrating technologies, related industries and different geographies. Simon Kollerup, Denmark's Minister of Industry, Business and Financial Affairs, unveiled two flagship projects, Mobile Industrial Robots (MiR) and Universal Robots (UR), which demonstrate a thriving Danish robotics industry. The robotics cluster provides members with opportunities to expand their network, accelerate growth and innovation, access funding, find new collaboration partners and increase visibility. Business support is provided to innovation and collaboration with knowledge institutions, but also for internationalisation.

One project in the robotic cluster is putting in place a collaborative construction site robot for assistive logistics tasks. This project focuses on exploring the possibilities for automation in the construction industry using mobile robots to help transport tools and materials. Construction relies on human-operated tools and machinery, which makes it an underutilised sector in terms of robotic automation. Enabling a mobile robot to navigate a construction site and help with these logistics tasks is the first step on the road to solving more complex tasks using robotics in construction. It was carefully tested how existing mobile robots can be adapted to perform a variety of logistics tasks around construction sites when equipped with additional sensors and perception algorithms.

Box 2: Cobot Knowledge Lab

The Danish robot clusters foster skills development through the so-called 'Cobot Knowledge Lab'. This lab helps SMEs learn how to operate cobots. The project is run by Odense Robotics in collaboration with Danish Technological Institute, DIRA, the University of Southern Denmark, Aarhus University and Fraunhofer IPA in Germany. The Industriens Fond has donated almost DKK 6 million to the Cobot Knowledge Lab. The consortium brings together unique competences within technology, business, management, organisation, 'human factors' and ethics that can support Denmark's leading position in the development and use of cobots. The consortium behind the project is developing an intensive course based on knowledge gained throughout the project targeting managers and employees of Danish manufacturing companies who are considering implementing cobots.



Source: Odense Robot Cluster, picture from Freepik

The processing of sensor data and extraction of high-level information about the surrounding environment, i.e. position of obstacles and humans, are vital for this application.

Skillnet Ireland is the national agency dedicated to the promotion and facilitation of workforce learning in Ireland. Its mission is to facilitate increased participation in enterprise training and workforce learning within SMEs[31].

The **Cobotics Skillnet** targets industries which provide economic impact of scale, namely; fintech, logistics, healthcare, retail and manufacturing. The objective is to remove barriers to job creation, job retention and competitiveness by boosting Irish 'robotic density'. The initiative provides training to both industry and graduates including new robotics apprenticeships.

In the **Netherlands**, the cabinet has recently laid down the implementation of the Technology Pact for 2021. It focuses on revised training needs at all levels and includes an action plan for change. The pact presents a long list of concrete and bold actions to address the digital and technological skills gap including training on AI and robotics.

Optimisation of work systems, Germany

The German Federal Institute for Occupational Health and Safety (BAuA)[32] is a departmental research institution of the Federal Ministry of Labour and Social Affairs. The institute is leading a range of studies and projects in topics such as new technologies and new forms of work, human-machine interaction and digital ergonomics. Deeper understanding of how technological change will affect the workplace is expected to contribute to a better design of future work systems. Digital ergonomics for example is understood as an "*umbrella term for digital models and methods for planning, realisation and ongoing improvement of products and socio-technical work systems*". Successful human-machine interactions need the ability of the technology to adapt to individual preferences.

With its interdisciplinary programme focused on 'Occupational Safety & Health in the Digital World of Work', the objective is to contribute to human-centred design of technological change. The programme has three components:

- Systematic data monitoring of technological change and its impact on working conditions.
- Task-specific analysis of the effects of digital change and the development of human-centred guiding principles for working in a digital world of work.
- Systematisation of new requirements for technical and organisational occupational safety.

Putting ethical guidelines into practice, France and Germany

The wider debate about ethical considerations around artificial intelligence is also pertinent at national level. Various guidelines have been published which raise similar questions such as the EU White Paper on AI. Nevertheless, as the report of the Bertelsmann Stiftung[33] (2020) also stressed, the next urgent step is to put these recommendations into practice. They draw attention to the importance of integrating ethical criteria from the start when developing any AI system.

One of the suggested proposals on the table is the creation of an **ethics label for AI systems[34]** to be used by AI developers to communicate the quality of their products. The advantage of such a label would be to inform the user how the system has been set up and if it follows the necessary ethical requirements.

In France, the national AI strategy presented in 2019 discusses, in particular, the impact of AI on labour and working conditions. Prior to the strategy, the French National Commission for Informatics and Freedoms (CNIL) conducted a public debate on algorithms and AI in 2017 with the aim of reflecting on the social issues raised by digital technologies [35]. It raised questions such as "*how to deal with the new forms of responsibilities that involve complex and highly segmented algorithmic systems*". Since algorithms allow the delegation of increasingly critical tasks including the machine reasoning, AI might be considered to be just and neutral, which might open the way to excessive trust. There is a need for human control mechanisms to avoid excessive depedency on, for example, machine-generated suggestions for critical decisions.

Another practical contribution to the ethical requirements debate is via the recently set up Artificial and Natural Intelligence Toulouse Institute (ANITI) in France, led by the University of Toulouse. The new institute targets strategic

[31] http://www.coboticsskillnet.ie/about/
[32] https://www.baua.de
[33] https://www.bertelsmann-stiftung.de/en/our-projects/ethics-of-algorithms/project-news/from-principles-to-practice-how-can-we-make-ai-ethics-measurable
[34] https://irights-lab.de/en/aiethicslabel/
[35] https://www.cnil.fr/fr/comment-permettre-lhomme-de-garder-la-main-rapport-sur-les-enjeux-ethiques-des-algorithmes-et-de

application sectors such as mobility/transportation and robotics/cobotics with the aim of supporting industrial transformation. By bringing together 200 researchers from universities, research organisations and companies, ANITI is expected to develop a new generation of artificial intelligence called hybrid AI, combining data-driven machine- learning techniques with symbolic and formal methods. Hybrid AI is expected to provide better guarantees in terms of reliability, robustness and the ability to explain and interpret the results of the algorithms used, while ensuring social acceptability and economic viability. The institute will also look into acceptability and fair representativeness of data for AI by integrating AI algorithms from social, economical, legal or ethical points of view. The research to be conducted will also propose new ways of handling data to address data bottlenecks and biases that can hamper AI systems.

Box 3: AI testing and quality

In Germany the Minister for Digital Strategy and Development of Hesse and VDE the Association for Electrical, Electronic and Information Technologies launched a plan in May 2021 to establish a nationwide **'AI Quality and Testing Hub '**. The aim of the initiative is to make the quality of AI systems verifiable. At the same time, the 'AI made in Hessen' trademark is also to be strengthened. Research and development as well as standardisation and certification will be put under one roof.

The four pillars of the AI Quality & Testing Hub will be:

- **Testing and checking**: test and simulation environments and testing laboratories will be put in place including research and further development of traceability, robustness and security.
- **Legal framework** for AI: AI applications are to be developed and tested under real conditions in order to prepare them to work also in practice.
- **Competencies**: this pillar includes the promotion of knowledge transfer between science and supervisory authorities as well as the development of AI quality competence among customers and operators in business and administration.
- **Change**: the last pillar reflects the transformative character of AI and includes support for companies, events and communication campaigns are also organised on how to foster the quality of AI applications.

Source: VDE, Germany, picture from Freepik

Section 3

3. Policy considerations

The potential in AI, robotics and other related digital technologies can unlock unprecedented opportunities not just to increase industrial competitiveness but also to address key societal challenges. In parallel with investing in technological development and fostering industrial uptake, policymakers and industrial stakeholders need to be aware of the risks and look for ways to support positive change. Realistic expectations need to be created about new technologies being implemented through collaborative human-machine interactions. Automated systems can carry out not only physical tasks but also a variety of cognitive tasks, such as assisting financial and legal work or medical diagnoses.

Beyond the advantages, human-machine systems can result in more sedentary work, less variation of tasks, but also cognitive underload and other forms of performance pressure. Risk factors such as isolation and lack of interaction with peers can have a negative impact on teamwork and potential psychosocial consequences.

In this short review of policy challenges and existing policy measures, the following observations can be made to inspire further policymaking:

The assessment of socio-economic impact and ethical, human-centred practices should be integrated throughout the technological value chain and in the policymaking lifecycle.

Firstly, right from the start technology experts and final users (including future employees) need to work together and jointly design the AI algorithms or robotics solutions to ensure the results are fit-for-purpose (‘fitness check’). Besides raising awareness of the beneficial effects of collaborative development and issuing guidelines that foster such a practice, policymakers can also foster human-centred design by integrating transparency requirements into AI-based products.

In the implementation of the latest national AI strategies new action plans could be created following some existing examples, as presented above, to consider the impact of collaborative AI/robotics systems on the workplace. Governance models can be put in place not just to manage change but also to monitor the short-term and long-term effects.

Although self-governance of tech companies (as stressed by the World Economic Forum) will be crucial to foster a positive industrial transformation, policy will need to carefully guide the process and mitigate associated risks.

AI-based systems will empower various industries including manufacturing, agriculture, healthcare and services, but will also change the content of these jobs and tasks to be performed. The new challenges that arise in the area of occupational safety and health (OSH) need to be considered more broadly. Current research conducted by various OSH agencies should not stay at the level of assessment, but should be integrated into AI and technological policies.

Skills development is high on the agenda both at European and national/local levels. The current debate is very much centred around the technology challenge and embedding technology/AI training into various curricula and education. Nevertheless, a too narrow technological focus might misunderstand, misstate or simply miss the potential in a collaborative AI/robotics setting. Skills policies could be ‘inspired’ to become more human-machine focused, where digital ergonomics and ethical considerations are taken seriously in parallel with enhancing technology knowledge. The future workforce should not only learn how to use technology, but also how to critically assess the advantages/disadvantages, and how to make positive decisions for the benefit of our society.

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About the 'Advanced Technologies for Industry' project

The EU's industrial policy strategy promotes the creation of a competitive European industry. In order to properly support the implementation of policies and initiatives, a systematic monitoring of technological trends and reliable, up-to-date data on advanced technologies is needed. To this end, the Advanced Technologies for Industry (ATI) project has been set up. The project provides policymakers, industry representatives and academia with:

- Statistical data on the production and use of advanced technologies including enabling conditions such as skills, investment or entrepreneurship
- Analytical reports such as on technological trends, sectoral insights and products
- Analyses of policy measures and policy tools related to the uptake of advanced technologies
- Analysis of technological trends in competing economies such as in the US, China or Japan
- Access to technology centres and innovation hubs across EU countries

You can find more information about the 16 technologies here: https://ati.ec.europa.eu.

The project is undertaken on behalf of the European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs and the European Innovation Council and SMEs Executive Agency (EISMEA) by IDC, Technopolis Group, Capgemini, Fraunhofer, IDEA Consult and NESTA.

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