Robotics4EU

Boosting Wider Adoption of Robotics in Europe

Responsible Robotics & non tech barriers to Inspection & Maintenance Robotics

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

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Table of Abbreviations and Acronyms

Abbreviation	Abbreviation
I&M	Inspection and Maintenance
AI	Artificial Intelligence
EU	European Union
AGVs	Automated Guided Vehicles
AMRs	Autonomous Mobile Robots

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1. Introduction

This report serves as an introduction to responsible robotics within Inspection & Maintenance. It does so by:

- explaining the current state-of-play of robotics in this area of application (Chapter 2),
- giving an overview of the general challenges within the field, and how specific dimensions relate to the development of socially acceptable robots that are, or can be, used within the field of Inspection & Maintenance (Chapter 3)
- and referring to relevant resources and tools that are available to support the responsible robotics community in building and adopting ethical and considerate robots (Chapter 4).

This document thereby presents the main findings drawn from research and stakeholder engagement activities (desktop research, co-creation workshops, citizen engagement workshops, policy research and workshops) conducted among robotics community members and policymakers during the Horizon Europe funded Coordination and Support Action project Robotics4EU (2021-2024).

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 in years 2021-2024, but also to collect further resources from the community in support of building responsible robots and raising the social acceptance potential of such robots in Inspection and Maintenance.

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.

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

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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 and the uptake of the legal, societal and ethical aspects of robotics;
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).

The Responsible Robotics Compass, 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.

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

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In support of developing the Responsible Robotics Compass – a tool created to assess robots social and ethical maturity – Robotics4EU executed a wide range of research and engagement activities (including 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 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 Inspection & Maintenance Robotics

2.1. General Application

Similarly to other fields of life, robots are adopted across industries to improve efficiency and precision by automating repetitive tasks, but also as a support mechanism. In addition, inspection and maintenance robots are usually equipped with smart sensors that ensure the safety of new, collaborative working methods where robots work alongside employees to help the staff in their regular tasks.

Striving for better quality control, error detection and easier adaptation to changes in the production process, the use of (mobile) inspection robots is most common in manufacturing and assembly work, especially in the automotive industry and electronics, but also in logistics, material handling and warehouse management. In construction, robots are used for maintenance and quality control but also progress monitoring, as-built modelling and safety inspection[3].

With the help of I&M robots, remote maintenance is made possible, which is especially useful for performing tasks in locations that are inaccessible or dangerous (e.g. underwater or mined areas). Again, smart sensors and technologies enable to receive, analyse and react to data fetched from afar, making on-location visits less necessary. At the same time, frequent and data-rich inspections are needed to improve error-detection and thereby also the confidence in related decision-making.

I&M robots also allow staff members to switch from acting and reacting to supervising, giving employees the option to perform less arduous and more gratifying tasks. For example, Automated Guided Vehicles (AGVs) and Autonomous Mobile Robots (AMRs) are used for logistical purposes, material handling and warehouse management where the products that are handled may be very fragile, hazardous and/or heavy. Robots thereby help to decrease or eliminate significant threats posed to employees' health and the economic loss related to ruined or broken goods.

This is certainly not an exhaustive list of opportunities, but rather a lean introduction to the main fields of application, which are in constant development.

2.2. Trends

Digital twins, machine learning and predictive maintenance | According to Scoutdi.com, virtual representatives of physical assets are popular in heavy industries to monitor and analyse real-time activities in a way that helps to predict potential future problems and opportunities for optimization. A clearer presentation of the perks of digitalization in a specific company is still needed as digital transformation is an investment that not all

[3] https://www.mdpi.com/2076-3417/13/4/2304

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companies find (financially) doable. AI-based robots are considered the best starting option. Inspection robots are ready to move on from generating and passing on rich information to analysing and reacting to certain predictable scenarios.

Autonomous inspection and operation | AGVs and AMRs are becoming accompanied by or upgraded to extremely mobile and nimble robots, which can access and operate in a larger variety of spaces, terrains[4] and positions like ANYmal that can take stairs, crawl, and jump in puddles, if needed.

Advanced sensors and imaging | Equipping robots with sophisticated sensor arrays, including LiDAR[5], ultrasonic sensors, and high-resolution cameras, enable them to perceive and analyze their surroundings with unprecedented precision as well as to detect defects, anomalies, and changes in real-time, contributing to predictive maintenance strategies. Furthermore, high-resolution cameras and imaging systems provide more detailed inputs for visual inspections and analysis.

Environmentally friendly solutions | With climate change showing its full spectrum across the globe, sustainability-first is becoming a demand that can no longer be overlooked. Robots of the future consider the full lifecycle of the product, considering the recycling and repurposing potential of the materials and components in use and opting for a smart design that minimises production waste.

Human-first solutions | Robots are being developed to help people, which means that they should also be extremely user-friendly and straightforward. In the upcoming years, it is no longer about making user interfaces clearer to professionals; robots are now appropriated to be intuitive enough also for non-experts and bystanders.

Soft robots | Most robots do not look like people, but many of them do. And as technology advances, human-like robots become more true to life. One way of doing this is by making them soft and (more or less) pleasant to touch. Think of robotic arms and prosthetics, or the most recent robotic mouth which gives sweethearts in long-distance relationships the opportunity to feel like they're kissing their loved one[6]. In the context of I&M robots, flexible robots (optomicrofluidics technologies) are developed, which are almost fluid. Guided by the light, the robot is able to pass through pipes, pump fluids and screw bolts.

Collaborative robots | Equipped with advanced sensors and AI, these robots are designed to work alongside human operators, enhancing efficiency and safety in inspection tasks. By combining human expertise with robotic precision, human-robot collaboration will improve flexibility, reduce downtime, and extend the capabilities of maintenance teams, especially in hazardous environments[7].

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[4] Diego Gitardi, Mattia Giardini & Anna Valente (2021) Autonomous robotic platform for inspection and repairing operations in harsh environments, International Journal of Computer Integrated Manufacturing, 34:6, 666-684, DOI: 10.1080/0951192X.2021.1925970

[5] LiDAR (Light Detection and Ranging) refers to the measurement of distance and room with lazers, which results in a detailed, 3D mapping of the surroundings that supports navigation.

[6] Chinese Students Made a 3D Kissing Device for Long-Distance Couples (businessinsider.com)

[7] R. Behrens and N. Elkmann, "A Revised Framework for Managing the Complexity of Contact Hazards in Collaborative Robotics," 2021 IEEE International Conference on Intelligence and Safety for Robotics (ISR), Tokoname, Japan, 2021, pp. 252-258, doi: 10.1109/ISR50024.2021.9419528.

2.3. Learnings from Robotics4EU

The Robotics4EU project organised co-creation workshops between Inspection & Maintenance robotics developers and end-users to discuss non-technological barriers which results are presented in D4.3 Co-creation Workshops to test robotics applications. The event(s) brought together stakeholders, researchers and end-users to discuss non-technological aspects of robotics within the field of Inspection and Maintenance. The discussions were framed around concrete robotic solutions that were presented by the developers and company representatives present at the workshop.

The central themes that came from the discussions of the workshop were:

A prominent shift is underway in the design and construction approaches of companies and projects, involving the incorporation of electric-driven solutions to contribute to a more sustainable future. This transition, coupled with the integration of AI and increased automation, not only reduces travel but also minimises the physical presence required at job sites, emphasising the potential for enhanced efficiency. The commitment to sustainability extends beyond design changes to component use, particularly batteries, often produced using conventional methods with considerable environmental impact. The imperative to adopt eco-friendly components is underscored, alongside the necessity for partnerships grounded in environmental commitments. This collective responsibility reinforces the industry's dedication to sustainable practices.

Addressing the absence of standards for damage caused by robotic systems and grappling with liability concerns, the workshop emphasised the need for clear guidelines and explicit legal agreements between developers and customers. Safety measures, including AI-driven awareness of surroundings and physical stop buttons on robots, are crucial elements in mitigating risks during close human-robot proximity. The challenges posed by varying legal guidelines across different countries underline the need for proactive measures to ensure uniformity in liability frameworks. Harmonising regulatory standards becomes imperative for the global integration of robotic solutions in inspection and maintenance practices.

A positive transformation in the job market is evident as robotic solutions undertake dangerous and physically demanding tasks, reducing physical strain on workers and allowing them to engage in more meaningful work. Trust-building measures, including improved communication interfaces and operator training, are highlighted as crucial aspects in fostering a harmonious human-robot working environment. Addressing challenges such as upskilling is pivotal in ensuring a smooth transition in the job market influenced by robotic development. Proactive solutions and educational initiatives are deemed essential for equipping workers with the necessary robotics skills, aligning with the changing work environment.

A significant barrier to adoption lies in the technical knowledge required for the effective operation of certain robotic solutions. The emphasis is placed on making these solutions more accessible to a broader user base, particularly targeting individuals with limited technical expertise, thereby democratising access to robotic advancements.

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Focus on ensuring well-defined methods to secure locally stored data is paramount, especially concerning privacy concerns related to human-robot collaboration, particularly in the presence of camera-equipped robots. Transparency, accountability, and privacy safeguards are identified as crucial elements in fostering a sense of security.

The workshop acknowledges financial structures as potential barriers in scaling and testing robotic solutions. Overcoming financial challenges and exploring innovative testing approaches are deemed crucial for the successful implementation of robotic solutions in inspection and maintenance practices.

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3. Challenges and Barriers for Robots in Inspection & Maintenance

This section goes into more detail, presenting the limiting and enabling factors of specific dimensions, such as ethics, socio-economics, data, and legal matters (see Figure 1). This knowledge is based on the workshops and research activities performed by the Robotics4EU consortium in the years 2021-2024.

Common Issues in responsible robotics

Socio-Economic Analysis

- Fear of tech unemployment
- Loss of worker autonomy
- Rising inequality in earnings
- Rising skill gaps and skill depreciation
- Uneven distribution of wealth
- Insufficient protection of worker rights (gig-economy)
- Policy issues
- Geographical disparity
- Digital divide
- Environmental problems

Ethics

- Safety and security at the workplace
- Lack of responsibility and accountability
- Lack of transparency & liability
- Infringements of traditional and cultural norms and values
- Gender inequality
- Insufficient protection of the minority groups
- Human rights abuse
- Negative impact on peace

Data

- Surveillance issue
- Lack of informed consent
- Lack of data control and
- Lack of contestability
- Vulnerability of cyber physical systems
- Cyberwarfare (social & political manipulation)
- Data theft (network security)
- Unbalanced power in data ownership

Legal

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

Education & Engagement

- Insufficient public engagement
- Lack of methods and empowerment
- Education issues (lack of resources, knowledge availability and informal science education)
- Inequality in development (education sector not following trends fast enough)
- Lack of trust in science
- Insufficient empowerment of the general public

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

3.1. Ethics in I&M robotics

In general, ethical issues encompass the possible negative consequences of robotics on human well-being, including safety and cybersecurity at the workplace, responsibility, quality of life and peace concerns. Robots may affect our autonomy, our sociability, and our sense of self. See also the Robotics4EU factsheet on Ethics in Responsible Robotics.

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Lack of responsibility and accountability
Lack of liability (identification)
Lack of transparency
Infringements of traditional and cultural norms and values
Gender inequality
Removing barriers to recruitment, retention, and career progression of women researchers
Gender imbalances in decision making
Integrating gender dimension in research and innovation content
Insufficient protection of the minority groups
Human rights abuse
Lack of integrity in the research itself
Negative impact on peace

Figure 2. Ethical issues within robotics, including I&M (Robotics4EU needs' analysis, 2021)

In the context of I&M robots, questions related to responsibility and accountability are especially relevant due to potential safety hazards related to the tasks: who is responsible when an intelligent robot causes an accident? Risk management and safety assurance are commonly referenced goals in robotics, but also the ability to notice errors and intervene in an automated process is as relevant in inspection and maintenance as it is in healthcare.

How an ethical approach is achieved, precisely, seems to vary widely between robotics fields. For example, risk management for healthcare robotics may revolve more tightly around security, accuracy, privacy, and patient outcomes; risk management in manufacturing might encompass values such as precision, speed, situational awareness, communication, collision avoidance, and failsafe mechanisms. The values that a field prizes as goals highly depend on the previously presumed "risks" in that field, automation design as well as robot task and aim programming. While approaches to addressing risk management and safety assurance are different, the challenge exists across all fields.

The defined ethical questions and issues also include gender imbalances, particularly in decision making roles, robotics research and the integration of gender dimensions in the research and innovation content. Although gender gaps in the research funding success rates are decreasing at EU level, men still have a higher success rate than women. 57% of tertiary graduates in the EU are women, but only 24.9% of them graduate in ICT-related fields, and very few enter the sector. In 2018, women made up 13% of the graduates in ICT-related fields working in digital jobs compared to 15% in 2011. While the numbers of women in science and engineering jobs are overall increasing throughout the years, females remain a minority share in such occupations[8].Globally, figures indicate that women's participation in the ICT and digital sector are not improving significantly.[9]

[8] From She Figures 2018: https://ec.europa.eu/info/publications/she-figures-2018_en
[9] From Women in the digital age: https://op.europa.eu/en/publication-detail/-/publication/84bd6dea-2351-11e8-ac73-01aa75ed71a1#document-info

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The lack of women's involvement in the robotics field may result in gender-biased AI system training, stemming from the lack of female perspective in data, research content, decision making as well as design and interface questions. The male-dominated workforce in robotics, which the inspection and maintenance workforce generally represents, is more likely to disregard female perspectives and concerns. This results in unintentionally excluding product users from engaging with the digital environment. AI systems therefore should be designed based on the perspectives, needs, expectations and contexts of all potential and current users.[10]

For **inspection and maintenance robots**, too, the systems developed are mostly using inputs given by the usual maintenance staff including male workers. The related technologies and guidelines created might thereby dismiss the needs of operating staff members who are of shorter height, have less strength and/or have a different (body) build.

3.2. Socioeconomics in I&M robotics

Socio-economic issues come down to a concern that robots are increasingly competing for jobs against humans, increasing skill, wealth and earnings gap and causing numerous policy-, worker rights and environmental issues in the socio-economic context.

A common concern for the future of work is that jobs are being eliminated and we are heading for a future of **mass technological unemployment**. While such fears are not new, there is no empirical support for the claims despite widespread workplace automation.[11] Nonetheless, robot applications do impact the job market, causing changes in labour and wealth distribution and regional and geographical disparity.

Job polarisation arises because many of the tasks performed by medium-skilled workers can be automated using digital technologies.[12] This trend, as well as the emergence of new wealth and last-mile work, shows that there is likely to be a fraction of jobs with relatively low human skill requirements which cannot be automated. Safeguarding the quality of these jobs in terms of **wages and non-wage characteristics such as autonomy** can become a key challenge in societies. This is even more important given how urbanisation impacts workers of different skill types, populating areas with high-skilled jobs, while the availability of middle-skill work has declined. [13]

Digitalization causes shifts in production, leading to a **reallocation of work across borders**, becoming an important force shaping the future of labour markets.[14] Apart from international impact in the allocation of work and workers, the **regional distribution** and the nature of those jobs have **also shifted within countries' borders**. A large body of research documents shows that high-skilled workers have increasingly moved to more densely populated (i.e., urban) areas over the last 35 years. This can lead to a digital divide on local, regional, and even international levels.

[10] From Artificial Intelligence and Gender Equality and Gender Equality: https://en.unesco.org/system/files/artificial_intelligence_and_gender_equality.pdf
[11] Mokyr, J. et al., "The History of Technological Anxiety and the Future of Economic Growth: Is This Time Different?" Journal of Economic Perspectives, 29 (2015): 31
[12] VoxEU, Sense and nonsense in the public discussion of the future of work. https://voxeu.org/content/sense-and-nonsense-public-discussion-future-work
[13] Autor, D.H., and Salomons, A. "New Frontiers: The Evolving Content and Geography of New Work in the 20th Century." (2019), Working Paper
[14] From INBOTS White Paper on Interactive Robots: http://inbots.eu/wp-content/uploads/2019/07/Attachment_0-1.pdf

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Increasing emphasis on automation and the role that interactive robots will play in the long-term economic prospects of the EU are the driving forces for new work forms and emerging market systems, calling for revised legislation. The need for robotics and labour market regulations becomes increasingly prevalent as 'new work forms' such as the 'gig economy' emerge. Workforce automation means that fewer on-site employees will be needed on a consistent basis, forming a hybrid workforce consisting of both robots and humans. Since robots can perform large volumes of manual and analytical work, constant human involvement is less needed. As automation becomes more sophisticated, human involvement will consist of tasks rather than jobs. Contractors will come and go according to organisational needs while robots increasingly make more and more decisions.

Evidence indicates that there is an increase in **new forms of work** that differ from the traditionally large groups of full-time workers with permanent contracts. The extent of worker protection rights in the gig-economy is an important issue to address. Temporary workers often must be registered as self-employed and cannot enjoy the same institutional and social protections, provided through full-time employment contracts, including but not limited to minimum hourly wage, paid holiday leave, parental leave, paid sick days and more. This type of work is also more on the rise amongst women and minorities.[15] Even though these issues may also appear in the ethical issues category, we address them here on a global, socio-economic level because they raise questions on **policy and legal regulations.** Changes in technology are usually followed by changes in policy. While this issue is frequently discussed in the circles of policymakers, it is **difficult to plan and enforce technology-related regulations and laws,** especially on an international level. Most of the developed policy is related to AI funding and AI policy emphasising requirements that new technological development must satisfy.[16] Public authorities can also support ethical technological developments by considering the overall societal impact of those technologies. Through a combination of voluntary policy measures and complementary regulation, more businesses will be obliged to integrate Sustainable Development Goals in their business models. This is how maximum societal value creation could be secured not only for shareholders and stakeholders but also for the society at large, accounting for the **social, environmental, ethical, consumer concerns and human rights.**[17]

Fear of technological unemployment
Loss of worker autonomy
Rising inequality in earnings
Rising skill gaps and skill depreciation
Uneven distribution of wealth
Insufficient protection of worker rights (gig-economy, platform economy)
Policy issues (subsidies, institutions, political agenda, digitalisation strategy)
Development of policy issue
Agents involved
Regional and geographical disparity
Digital divide
Environmental harm (harmful materials, greater energy consumption, harm to animals)

See also the Robotics4EU factsheet on socio-economic matters in responsible robotics.

[15] Katz, L.F., and Krueger, A.B. "The Rise and Nature of Alternative Work Arrangements in the United States, 1995–2015." Industrial & labour Relations Review 72 (2019): 382–416
[16] AI HLEG, 2019, "High-Level Expert Group on Artificial Intelligence: Ethics Guidelines for Trustworthy AI". European Commission, 09.04.2019. https://ec.europa.eu/digitalsingle-market/en/news/ethics-guidelines-trustworthy-ai

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3.3. Data in I&M robotics

Privacy and security. Smart devices and IoT-based systems are a potential threat to privacy and data protection due to the mass collection of data and can enable forms of social control and political manipulation. Intelligent software agents may raise concerns in relation to privacy and data protection, responsibility, and accountability. Here dangers of data mining involving sensitive information and the misuse of online insights (navigation, communication, location, purchase behaviour, consumption) were identified. These issues endanger the core values of privacy protection broadly impacting society.

Digital security is the economic and social facet of cybersecurity, concerning all stakeholders: businesses, public administrations, other organisations, and individuals. It has an impact on assets, safety, reputation, opportunities, and economic and social activity continuity. As a result, challenges regarding disrupting the availability, integrity and confidentiality of hardware, software, networks, and data arise. Big data creates issues such as data driven discrimination due to automated decision making. In this context, big data can cause a shift in power due to the new data divide, based on who owns, collects, and analyses the data.

Digital technology enables a new paradigm of open science, which has three main pillars: open access to scientific publications and information; enhanced access to research data; and broader engagement with stakeholders. Digital technology is also enlarging the process of discovery. Open science could make science more efficient and effective and streamline the translation of research findings into innovation and socio-economic benefits. However, this shift also requires policy adjustments.

Surveillance issues (authorization, transparency, legal mandate, online/offline activity monitoring)
Lack of informed consent
Lack of control and empowerment about access to data (including personal data)
Lack of contestability (lack of options, ability to choose to share your data)
Vulnerability of cyber physical systems
Cyberwarfare (social control and political manipulation)
Data theft (issue of network security)
Unbalanced power in data ownership

See also the Robotics4EU factsheet on socio-economic matters in responsible robotics.

3.4. Legal matters in I&M robotics

Legal issues include having clear definitions and ensuring liability in terms of civil law rules on robotics, testing, and privacy regulations. The rise of interactive robotics brings a considerable challenge for the law: how should the law deal with robot-assisted inventions and human-robot co-creation? Indeed, the probabilistic nature of AI-driven software and the complexity of rule-based algorithms could theoretically lead the robots to learn how to produce new works and inventions. In this context, a debate of such ownership arises; if robots or AI applications

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become capable of inventing original products and ideas (potentially subject to protection by copyright, patents, designs and trade secrets) who should own them?[18] If the worker trains the robot to perform a certain action, or in some form enhances the productivity of the robot by improving on existing capacities, should the worker also be entitled to IP rights/patent rights, or do the rights belong to the robot's manufacturer? Newest advances in robotics expose the potential for independent robot creativity in the future through evolutionary or genetic algorithms allowing machines to devise new, un-bias data sets.[19] Rapid machine learning and genetic algorithms are already being used in search of clean energy materials. If initiatives as such prove to be successful, the theoretical debate on legal robot creation and discovery protection might have to turn to practical implementation.

Arising legal issues include the lack of global governance (not having a unitary body of rules for all kinds of robotic applications), absence of legal framework for testing, intellectual property infringement, lack and lag in regulatory development due to the fast pace of technological development and its adoption in the modern workplace (including the lack of clear regulations for free flow of data). The current legal framework covers machinery and intellectual property rights, but the advent of autonomous and semi-autonomous systems enabled by AI, requires further regulatory development.

To continue technological development without restraint, the legal employment framework should address a "safety net" concept as a transition period. Vulnerability of certain groups (based on age, gender, ability etc.) must be considered while the existing workforce adjusts to the new technological developments and applications. Another potential solution could be positive discrimination measures, or affirmative action in favour of human workers. Companies would be encouraged to satisfy quotas of human workers, while implementing training programmes to facilitate employee transition into a more technologically advanced working environment.

Lack of awareness and legal frameworks in human enhancement technologies is an extensive legal issue, affecting the perception of human rights. Human enhancement technologies allow humans to perform beyond their natural biological capacities with the help of technology.[20] While various enhancement devices such as neurostimulators, pacemakers or activity trackers (e.g., smart accessories) are widely used in medical settings, their regulation beyond healthcare is practically inexistent. Firstly, it causes legal questions and concerns for human dignity as some people might feel pressured to use enhancement devices to keep up with the increasing standards at work. Secondly, since the technology is novel and potentially vulnerable to hacking, data breaches are likely to occur alongside malicious manipulation of device purpose. Since smart devices collect and store large amounts of personal information, the potential to cause harm is high and the legal framework must consider security implications and criminal liability for such data breaches. Meanwhile, free data flow and collection are essential to the device's main function and purpose. Now, there is no specific regulatory system governing human enhancement devices beyond the scope of product safety requirements.[21]

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[18] From INBOTS White Paper on Interactive Robots: http://inbots.eu/wp-content/uploads/2019/07/Attachment_0-1.pdf pp 22-25
[19] Jennings, P.C., Lysgaard, S., Hummelshøj, J.S. et al. Genetic algorithms for computational materials discovery accelerated by machine learning. npj Comput Mater 5, 46 (2019). https://doi.org/10.1038/s41524-019-0181-4
[20] Konrad Siemaszko, Rowena Rodrigues, & Santa Slokenberga. 2020. SIENNA D5.6: Recommendations for the enhancement of the existing legal frameworks for genomics, human enhancement, and AI and robotics. Zenodo. http://doi.org/10.5281/zenodo.4121082.
[21] Konrad Siemaszko, Rowena Rodrigues, & Santa Slokenberga. 2020. SIENNA D5.6: Recommendations for the enhancement of the existing legal frameworks for genomics, human enhancement, and AI and robotics. Zenodo. http://doi.org/10.5281/zenodo.4121082.

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Other policy issues responding to robotic automation and its taxation regulation may arise as well. A tax on robots would be particularly difficult to design and implement because estimating the extent of robotic involvement in profit generation is nearly impossible. Additionally, a tax on robots raises questions about the intention of such a measure. It can be designed as a fiscal measure to compensate for the decrease in tax coming from employed human labour, however, this approach would be difficult to justify given that in Germany and Japan, with relatively high robot density, unemployment is much lower. [22]

Intellectual property infringement
Lack of global governance
Not having a unitary body of rules for all kinds of robotic applications
Absence of legal framework for testing
Other policy issues
Lack of and lag in regulatory development
Lack of compliance to GDPR
GDPR seen as not sufficient
Unclear and unharmonized regulations (inconsistent sets of rules for human-machine cooperation)
Lack of awareness of the legal rights related to data and technology
Absence of legal standards to ensure privacy and free flow of data
3D printing, privacy and intellectual property

Read more about the legal dimensions in responsible robotics from the Robotics4EU report here.

3.5. Education and management in I&M robotics

Digital technology is providing new tools that are revolutionising institutional relationships and the way society operates, empowering individuals, and their ability to actively participate in societal processes, and contribute to decision-making and production. Effective interaction between public administrations, citizens and businesses is essential to building a digital society. However, the information and resources on technology integration that governments and public administrations provide for citizens can be difficult to understand. This leads to a sense of detachment between the public bodies and the democratic process itself.[23]

Education systems are critically important for innovation through the development of skills and networks that nurture new ideas and technologies. However, whereas digital technologies are profoundly changing the way we work, communicate, and enjoy ourselves, the world of education and learning is not yet experiencing the same technology-driven innovation process as other sectors. There is a general lack of research concerning the issues in education, shortfall in scientists at all levels of society as well as science education outside the classroom (informal science education) and its effects of non-educational activities. When the public education system is not following the change imposed by technological development, the

[22] From INBOTS White Paper on Interactive Robots: http://inbots.eu/wp-content/uploads/2019/07/Attachment_0-1.pdf , pp 106-107
[23] From HubIT: https://www.hubit-project.eu/key-challenges

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inequality gap widens between those who have access to modern technologies and those who are constrained by their environment and social status. This creates an unfair advantage for privileged groups giving them exclusive access to opportunities that should otherwise be widely accessible.

On the other hand, the rapid diffusion of open access publications and science-related news online increases opportunities for all citizens to access and generate science-related content. However, the lack of editorial oversight and fact-checking established in the traditional media increases the likelihood of such information being misleading or incorrect. Spontaneous news on social media causes a rapid spread of misinformation and thus further widens the separation between science and the general public.

Insufficient public engagement
Lack of empowerment
Lack of methods for engagement and empowerment
Education issues (lack of education resources, shortfall in science knowledgeable people,
shortfall of informal science education)
Equality
Inequality in development (education sector not following trends fast enough)
Lack of credibility and authority given by general public to science (diminishing trust)
Lack of empowerment of general public

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The work of identification and classification overlooks a wide and extensive range of issues associated with digitalisation and open innovation from both general and industry-specific perspectives. Desk research shows that the investigation into ethical, legal, privacy, cybersecurity and socio-economic issues tends to focus on specific problems rather than explore the comprehensive impact of those problems on European robotics' growth. For this reason, the current deliverable aims to analyse and connect those concerns under an all-inclusive system, providing a consolidated issue analysis.

4. Solutions and Resources

In the wide landscape of the Inspection & Maintenance industry, it becomes increasingly important to imagine positive future states guided by Responsible Robotics principles. Doing so can lead to better and improved implementation of robotics today. This subchapter details what one of these future states could look like by leveraging frontier technologies while prioritising ethical considerations.

Autonomous systems, equipped with advanced sensors and artificial intelligence, become integral to streamlined inspection and maintenance processes. These robots navigate intricate environments independently, conducting tasks efficiently and with an increased focus on safety.

In the near future, the workforce dynamics undergo a positive transformation towards augmentation rather than displacement. Robots and human workers collaborate seamlessly, with robots handling routine and hazardous tasks, allowing human workers to focus on complex decision-making and innovative problem-solving. In this case, workforce development programs play a vital role in equipping individuals with the skills necessary for operating and managing robotic systems in a collaborative environment. This stresses the importance of education and training initiatives in preparing individuals for the evolving job market which pushes the involvement of industry players to become part of the educational system.

Additionally, the narrative emphasises a commitment to transparency, accountability, and privacy safeguards embedded into the design of robotic systems. This approach addresses concerns related to data collection and human-robot collaboration. The emphasis on ethical development and adherence to global standards fosters innovation, establishing a foundation for the widespread acceptance and ethical application of inspection and maintenance robotics.

4.1. Key Initiatives and Organisations to Follow

The adoption of inspection and maintenance robotics in various industries offers promising solutions to enhance operational efficiency, safety, and sustainability. However, the successful integration of these technologies faces not only technical challenges but also non-technological barriers that must be addressed for widespread acceptance. We hereby want to shed some light on two prominent European initiatives, SPRINT Robotics and the RIMA Network, which have been pivotal in tackling these barriers and promoting the adoption of inspection and maintenance robotics across industries.

SPRINT Robotics | Not-for-profit organisation and has become an internationally recognized platform for I&M Robotics with a support base of more than 100 organisations around the globe.

One of the core strengths of SPRINT Robotics lies in its ability to foster collaboration and knowledge sharing among stakeholders. The initiative hosts regular events, workshops, and conferences where experts and professionals exchange ideas, experiences, and insights. This

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collaborative approach not only accelerates technological advancements but also helps in creating a community that supports the integration of inspection and maintenance robotics in various sectors.

The organisation actively engages with regulatory bodies and industry associations to develop guidelines and standards that ensure the safe and compliant deployment of robotic systems in diverse industrial environments.

The Robotics for Inspection and Maintenance Association (RIMA) | Functioning as a collaborative hub, it transcends geographical boundaries to unite experts and resources. This unification expedites the development and standardisation of robotic solutions, propelling the industry forward through shared knowledge and expertise.

RIMA Network also provides financial and entrepreneurial support to startups and SMEs (Small and Medium-sized Enterprises) involved in inspection and maintenance robotics. By offering funding opportunities, access to infrastructure, and mentorship, RIMA aims to nurture a thriving ecosystem of robotics entrepreneurs, helping them navigate the complexities of commercialization and scaling.

In Europe, initiatives like SPRINT Robotics and the RIMA Network are essential pillars in the effort to overcome non-technological barriers to inspection and maintenance robotics adoption. By actively addressing issues related to regulation, safety, market access, and collaboration, these organisations play a pivotal role in accelerating the integration of robotic technologies across industries, ultimately contributing to increased operational efficiency, safety, and sustainability on a broad scale. As inspection and maintenance robotics continue to evolve, the collaborative efforts of such initiatives become increasingly critical for unlocking their full potential.

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4.2. Relevant Publications and Regulations

The advent of robotics has revolutionised various fields, including inspection and maintenance. The responsible use of this technology is a topic of growing interest among researchers and practitioners. This chapter aims to provide an overview of the key peer-reviewed publications and journals that contribute to this discourse.

Institution, publication	Focus Areas
Robotics, AI, and Humanity	Published works such as "Responsible Robotics and Responsibility Attribution" which discusses the importance of human responsibility in establishing clear robotics policies and regulations. More specifically "Responsible Robotics and Responsibility Attribution" by Wynsberghe 2021.
European Association for the Advancement of Robotics in Europe: euRobotics	Research and innovation in European robotics; Publications may provide insights into responsible robotics and developments in inspection and maintenance.
International Federation of Robotics: IFR	Global trends and developments in robotics; Reports may cover aspects relevant to inspection and maintenance.
International Journal of Advanced Robotic Systems: IJARS	Open-access journal covering multiple areas of robotics, providing insights into advanced systems and responsible practices.
Zenodo: Impact assessment report	Report assessing the impact of an aerial inspection and maintenance drone with regards to privacy risks.
Open Access Robotics Journals: OA.mg	A list of journals for publishing robotics' content.

4.3. Regulations

In the domain of Inspection and Maintenance, the role of regulations cannot be overstated. These regulations are the cornerstone of ensuring the responsible and safe deployment of robotic technologies. They serve a dual purpose: firstly, to establish the essential prerequisites that robotic systems must meet before their use, and secondly, to assign responsibility in case of accidents. The overarching goal is to ensure the safe operation of these systems for the well-being of individuals and society at large. In a rapidly evolving technological landscape, the need for robust regulatory frameworks has never been more apparent.

For a detailed overview of Inspection and Maintenance regulation please refer to the: "Review of legal frameworks, standards and best practices in verification and assurance for infrastructure inspection robotics" composed by the RIMA network in 2018.

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The EU does not yet have specific legislation on robotics. Nevertheless, as products, robotics are regulated by a variety of legislative frameworks, including horizontal legislation, such as the Directive on Liability for Defective Products and the Product Safety Directive. The following is a list of notable regulations that apply to the development and use of robotics in the European Union:

The European Parliament has adopted Civil Law Rules on Robotics. This document provides recommendations to the Commission on Civil Law Rules on Robotics and addresses the need for a generally accepted definition of a robot and AI that is flexible and does not hinder innovation.

The European Parliament's Legal Affairs Committee commissioned a study to evaluate and analyse, from a legal and ethical perspective, a number of future European civil law rules in robotics.

Machinery Regulation 2023/1320 | is a key piece of legislation that applies to the development and use of robotics in Europe. This regulation replaced the previous Directive 2006/42/EC on machinery. The regulation defines the mandatory essential health and safety requirements that machinery products must fulfil to be placed on the European market. The technical details are mainly provided through European harmonised standards elaborated by European standards organisations. The Machinery Regulation also intends to better cover new technologies such as autonomous mobile machinery (robots), the internet of things with connected equipment, or artificial intelligence (AI), where specific modules of AI using learning techniques ensure safety functions. The regulation applies to machinery and related products: interchangeable equipment; safety components; lifting accessories; chains, ropes and webbing; and removable mechanical transmission devices. And, also to partly complete machinery. Several types of equipment are excluded from the scope of the Regulation such as motor vehicles and their trailers, specific equipment used in fairgrounds or amusement parks or machinery specially designed and constructed for research purposes for temporary use in laboratories. The objective of the Machinery Regulation is to allow that machinery, related products as well as partly completed machinery to be made available on the market while ensuring a high level of protection of the health and safety of persons, in particular consumers and professional users.

The upcoming **Artificial Intelligence Act** proposed by the European Union is a comprehensive legal framework that aims to regulate the development and use of artificial intelligence (AI) systems in the EU. Here are some key points about the Act:

- The Act classifies AI systems by risk and mandates various development and use requirements.
- It aims to strengthen rules around data quality, transparency, human oversight, and accountability.
- The Act also addresses ethical questions and implementation challenges in various sectors ranging from healthcare and education to finance and energy.
- In June 2023, changes to the draft Artificial Intelligence Act were agreed on, to now include a ban on the use of AI technology in biometric surveillance and for generative AI systems like ChatGPT to disclose AI-generated content.

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- The Act aims to ensure the proper functioning of the EU single market by setting consistent standards for AI systems across EU member states.
- It seeks to foster innovation and competitiveness in the AI sector, while ensuring that AI systems respect EU values and rules.

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5. Conclusions

In conclusion, this report has given a detailed look at the current state of Inspection & Maintenance (I&M) robotics, with a focus on responsible robotics principles. Chapter 3 delved into the various challenges and barriers, covering ethical, socio-economic, data-related, legal, and educational aspects that impact robot development in I&M.

The insights and tools proposed in this report provide a practical start for the ongoing development of responsible robotics. Moving forward, these findings offer a guide for collaboration among stakeholders, including the general public, roboticists, and end-users. By working together to address the ethical, legal, and societal considerations in robotics for I&M, we aim to ensure safe and widespread robot adoption in these important areas.

This report reflects our commitment to clear communication, inclusivity, and responsible practices, recognizing the perspectives of the general public, roboticists, and end-users. We believe that the insights and recommendations shared here will resonate with and contribute to discussions among these key stakeholders in the robotics field.

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