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legal regulations of industrial robots

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Journal of Information Technology, Cybersecurity, and Artificial Intelligence, 2025, 2(2), 26–33

Article DOI: <https://doi.org/10.70715/jitcai.2025.v2.i2.014>

Abstract

This study examines the legal nature of industrial robots in light of the rapid progress in artificial intelligence technologies and the growing reliance on such systems in various aspects of life. It raises new legal and ethical questions about the extent to which industrial robots can be granted legal personality, and the forms and nature of such personality. The study discusses this concept as a legal framework that permits attributing certain rights or obligations to robots, depending on their use and degree of functional independence from humans. The importance of this discussion becomes evident with the emergence of advanced applications of industrial robots, such as self-driving cars, production-line robots, chatbots, and algorithms capable of making impactful decisions that may cause material or moral harm without direct human intervention. The study further investigates whether the legal system needs to adopt a special model of legal personality for these entities to enable accountability for their actions or the outcomes of their decisions.

Using the descriptive-analytical approach, the study centered on the following question: What is the legal nature of industrial robots? The study concludes that granting robots a special or conditional legal personality may help fill the legislative gap concerning liability, particularly in cases where tracing the direct human actor proves difficult. The findings emphasize the necessity of establishing gradual and balanced legal frameworks through which industrial robots can be granted limited and well-regulated legal personality. Such frameworks must both account for technological advancement and ensure effective human oversight. The study also calls for international cooperation to formulate unified legal standards consistent with legal and human values.

Keywords: *Industrial robots, Artificial Intelligence, Self-driving cars, Chatbots, Production-line robots.*

Introduction

In recent decades, modern industries have witnessed remarkable development due to rapid technological advancement, which has not only improved tools and equipment but has also revolutionized the way production processes are executed. One of the most significant transformations has been the introduction of various types of industrial robots into production lines, giving rise to the concept of “*smart factories*” that rely on automation, digital control, and deep integration with artificial intelligence (AI) and the Internet of Things (IoT).

In this context, robots have assumed a pivotal role in redefining the concept of work within factories. They are no longer mere mechanical arms programmed to perform specific tasks; rather, they have evolved into intelligent entities capable of learning, interacting, and self-improvement. Modern industrial robots can safely operate alongside humans, navigate autonomously within work environments, or even perform self-maintenance.

The integration of technologies such as augmented reality (AR) and virtual reality (VR) has enabled workers to interact with robots more efficiently and safely, while AI allows robots to analyze data and make real-time decisions, enhancing production efficiency, reducing waste, and improving quality.

Accordingly, this study focuses on the legal framework governing industrial robots, aiming to answer the following questions: What is the legal nature of industrial robots? Do they possess recognized legal personality? If such recognition were granted, it would entail assigning legal responsibility to robots for any damages resulting from their actions or decisions. The study aims to review the most significant transformations and recent trends in the field of industrial robotics, from collaborative robots and self-maintaining robots to full automation. It also highlights the integration of these robots with the IoT and their role in enhancing industrial flexibility and adapting to modern market challenges.

The study adopts a descriptive-analytical methodology, aiming to describe and analyze the legal framework governing artificial intelligence and industrial robots. It also includes a technical review of AI and industrial robotics to clarify the relationship between technology and law. The study is divided into two main sections. The first section addresses the nature of industrial robots and their associated systems, while the second focuses on the legal framework regulating industrial robots.

1.1. Section One: The Nature of Industrial Robots and Their Associated Systems

Industrial robots are defined as mechanical machines operating under computer systems programmed to perform specific human-defined tasks. Industrial robots come in various forms, which are discussed in the following subsection, while the subsequent subsection addresses the intelligent systems associated with them.

1.2. Subsection One: Types of Industrial Robots

The forms and functions of industrial robots vary according to their tasks and level of sophistication and can be classified as follows:

1.2.1. Collaborative Robots (Cobots)

Collaborative robots, or “Cobots”, are a new generation of industrial robots designed to work safely and seamlessly alongside humans. Unlike traditional robots, which must be isolated within cages or restricted areas to prevent injury, cobots are equipped with advanced safety technologies that stop their operation immediately upon human contact, significantly reducing the risk of accidents. They also operate with limited force, ensuring safety in shared workspaces.

Cobots are easy to use; researchers note that they require no advanced programming skills. Workers can train them simply by moving their arms to demonstrate the required motions, or via user-friendly drag-and-drop interfaces, and even through voice commands in some advanced models. These robots are highly flexible, allowing relocation between workstations without major modifications to factory infrastructure.

A key advantage of cobots is their cost-effectiveness, as they require relatively low investment for installation and security, making them accessible even to small and medium-sized enterprises. Today, they are used in various applications, such as assisting in automotive assembly, assembling delicate electronic components, or handling packaging and sterilization in the food and medical industries. Studies project that cobot adoption in factories will increase by more than 40% in the coming years, particularly within smart factory systems, where AI enhances their understanding and responsiveness to human instructions (Farah, 2019: 160).

2. Self-Maintaining Robots

Self-maintaining robots are an advanced type of industrial robot capable of monitoring their internal condition and diagnosing faults independently. For example, if a motor overheats, the robot automatically shuts down and alerts the maintenance team. In some cases, it can even take temporary corrective measures until human intervention occurs.

These robots rely on internal sensors measuring various indicators, such as vibration, temperature, pressure, and energy consumption. Data is analyzed by an AI system that compares current performance with optimal benchmarks to detect potential malfunctions. When a fault is detected, the robot may adjust its operation—such as reducing speed—or use alternative tools if available.

These capabilities reduce downtime, lower maintenance costs, and enhance workplace safety by minimizing the risk of sudden equipment failures (Azab, 2021: 115).

3. Flexible Industrial Robots

Flexible industrial robots are not limited to a single task; they can perform multiple functions and adapt easily to changes in production lines. Tools and programming can be adjusted quickly without significant time or expense.

Researchers highlight that such robots are ideal in dynamic industrial environments where products or production volumes frequently change, such as electronics manufacturing or 3D printing. Some models utilize AI to quickly learn new tasks by observing workers or interacting with digital designs.

The result is a highly adaptable production line that can respond to market demands without long downtimes or infrastructure redesign (AlHadri, 2018: 16).

4. Mobile Industrial Robots

Mobile industrial robots differ from traditional stationary robots as they can move freely within factories or warehouses. Equipped with advanced technologies such as LiDAR sensors and cameras, these robots can navigate autonomously and avoid obstacles without fixed tracks.

They are used to transport components within factories, distribute materials in warehouses, or deliver products between departments. Some modern models can communicate with other robots and inventory management systems, forming an integrated intelligent network.

This type of robot enhances internal logistics efficiency, reduces human intervention, and contributes to faster production with fewer errors (Sotnik, 2022: 40).

Researchers note that the diversity in types and functions of industrial robots reflects the advancement of AI and the expanding scope of its applications in industrial and other domains. From collaborative robots to mobile industrial robots, these entities vary in intelligence, autonomy, and interaction with their environment. This variability requires careful regulatory and legal attention to ensure that each type's unique characteristics are recognized and that robots are not treated as a single uniform legal or technical entity. Understanding the forms of industrial robots in depth is thus essential for any legal framework seeking to regulate the human-robot relationship.

4.1. Subsection Two: Intelligent Systems Related to Industrial Robots

Artificial intelligence (AI) refers to the ability of machines to simulate intelligent human behavior, such as reasoning, analysis, and decision-making. Machine learning, according to researchers, is a branch of AI that enables robots to learn from data and past experiences, thereby improving their performance without the need for reprogramming each time. When these technologies are integrated with industrial robots, they gain the ability to analyze data collected during operations—such as temperature, movement speed, and error frequency—and use it to enhance performance and detect potential problems before they occur. Through computer vision, AI-powered cameras can identify correct or defective parts, thereby ensuring highly precise quality control.

Robots can also learn through experience by testing multiple methods of performing a task and selecting the most effective one. They can apply predictive maintenance to anticipate potential failures based on usage patterns, thus reducing costly downtime. Moreover, they can autonomously adapt to environmental variables, such as changes in the location or size of components, without human intervention.

Collectively, these capabilities make intelligent robots highly effective tools for improving production efficiency and reducing waste, while also saving time and effort that would otherwise be spent on repairs or reprogramming (Magdy, 2020, p. 5).

Accordingly, several modern systems in the operation of industrial robots can be highlighted as follows:

4.1.1. Integration of Augmented Reality (AR) and Virtual Reality (VR) in Robot Operations

Augmented reality is a technology that overlays digital information on what humans perceive in the real world, whereas virtual reality is a three-dimensional digital environment that fully simulates reality. When combined with industrial robots, these technologies provide significant opportunities for training and operations.

For example, researchers suggest that new employees can be trained in a fully simulated industrial environment without the need to operate real equipment, thereby reducing operational errors and accelerating the learning process. Engineers can also control a robot arm remotely via VR headsets without exposing themselves to any danger.

Additionally, when a robot malfunctions, maintenance technicians can wear AR glasses displaying digital step-by-step repair instructions. The display can also be shared with experts in other countries, allowing them to provide remote audio-visual guidance. This approach makes maintenance faster, easier, and more accurate, even in emergency situations (Ayad, 2023, p. 12).

4.1.2. Integration with the Internet of Things (IoT)

The Internet of Things refers to the interconnection of devices and industrial equipment via the internet, enabling them to exchange data and make decisions without direct human intervention. When industrial robots are integrated into this system, they can operate harmoniously with other elements of a smart factory.

For instance, a robot may transmit real-time data to a central monitoring system or receive updated instructions based on actual factory conditions. With the support of data analytics, the system can predict failures, issue early warnings, or automatically adjust task priorities. Researchers argue that such integration fosters a flexible, intelligent, and responsive production environment, while also reducing costs by optimizing resource use and preventing waste (Al-Bahi, 2019).

4.1.3. Full Automation

Full automation represents the final stage of industrial transformation, in which all stages of production are carried out without human intervention—from receiving raw materials to packaging the final product. This is achieved through a fully integrated system of robots, digital control mechanisms, artificial intelligence, and IoT.

In this model, researchers note that operations can be managed entirely autonomously, with quality control and maintenance supervised by intelligent systems. For instance, an automotive production line can operate continuously, day and night, without the need for human workers—what is often referred to as a “dark factory,” meaning a factory that functions without the need for lighting because no human presence is required.

Such automation results in dramatic increases in productivity, improvements in quality, and cost reductions. However, it also requires substantial initial investments and highly skilled workers. For this reason, a gradual transition is recommended, alongside training and capacity building to meet the demands of the new work environment.

Ultimately, these robots and their associated technologies represent the future of industry, where factories become smarter, more productive, and more adaptable to the accelerating pace of economic and technological change (Automation: Definition, Types, Importance, and Uses, 2025).

In summary, researchers emphasize that the diversity of robot forms and the multiplicity of intelligent systems associated with them reflect an advanced technological reality that poses unconventional challenges. This necessitates a profound understanding of such entities in order to develop a balanced regulatory vision that keeps pace with this transformation.

4.2. Section Two: The Legal Framework Governing Industrial Robots

The significant advancements in the field of industrial robotics necessitate a reconsideration of the legal frameworks governing them. Legislators did not anticipate that vehicles—traditionally classified as objects—would be equipped with artificial intelligence systems enabling autonomous driving and independent decision-making that adapts to their environment. This development grants such entities a unique legal character, moving them beyond the conventional category of objects into a novel domain that requires unprecedented legal treatment (Al-Khouli, 2021: 245).

While no Arab legislation has yet directly regulated intelligent robots through a dedicated law or independent statute, South Korea stands out as a pioneering country in this domain. In 2008, it enacted Law No. 9014, later amended by Law No. 13744 in 2016, titled “*Law on the Development of Intelligent Robots and the Promotion of Distribution*.” This law comprises three main sections: the first establishes standards for robot manufacturing, the second defines the rights

and responsibilities of users and owners, and the third addresses the rights and responsibilities of the robots themselves. Article 2 of the law defines an intelligent robot as "a mechanical tool capable of perceiving its external environment, distinguishing surrounding conditions, and acting voluntarily" (Mohammed, 2021: 28).

4.3. Subsection One: Legal Personality of Industrial Robots

The concept of granting legal personality to industrial robots is highly controversial, particularly given the rapid development of these technologies. Some scholars argue that legal recognition may become a future necessity, while others caution against the legal implications of such recognition. The debate is further complicated by differing perspectives on the nature of industrial robots: some view them as material entities due to their reliance on tangible hardware, others as immaterial due to the software driving them, while a third perspective considers them a combination of both (Batikh, 2022: 64).

Natural persons possess full legal personality, encompassing multiple rights and duties, such as the rights to marry, own property, inherit, and exercise political rights—none of which can be granted to non-human entities. Legal persons (juridical entities) are independent legal entities created by a group of individuals or financial resources, endowed with specific rights and duties, but their decision-making is supervised and managed by humans, lacking complete autonomy. On the other hand, artificial intelligence and industrial robots—used to perform precise, specific tasks—develop rapidly and may become capable of complex decision-making. However, they do not possess legal personality or moral capacities that would confer independent legal status. They remain tools operated and managed by humans, and under current legal systems cannot be considered independent legal entities (Al-Da'ja, 2024: 956).

Some legal scholars have proposed the "*bundle theory of legal personality*," suggesting that industrial robots could be granted legal personality composed of a set of attributes appropriate to their nature as intelligent machines. Accordingly, industrial robots could be endowed with certain rights and obligations analogous to those of natural and juridical persons. The goal is to recognize artificial intelligence systems as electronic persons with a distinct legal status (Ibrahim, 2022: 135).

Given that legislatures have recognized juridical personality as a virtual entity, it is conceivable to grant industrial robots and intelligent systems a form of special legal personality, distinct from natural or traditional juridical persons—a third type combining elements of both. However, direct legal liability should not currently be assigned to industrial robots, as they still operate under human guidance and lack full autonomy in decision-making. Furthermore, they do not possess the legal capacity or financial ability to bear obligations, precluding accountability for their actions at this stage (Al-Da'ja, 2024: 957).

This approach implies granting artificial intelligence, including advanced industrial robots, a legal personality with *capacity for rights and duties without capacity for performance*, taking into account their unique characteristics and absence of human-like faculties. AI and industrial robots would be granted specific rights and obligations—excluding those inherent to natural persons—through registration in official records with identification numbers, potentially linked to a trade name or distinctive mark. Simultaneously, human oversight remains essential, with responsibility retained by producers, operators, or owners for the actions of AI systems and industrial robots. Liability could be reinforced through mandatory insurance or compensation funds to address potential damages (Al-Da'ja, 2022: 40).

Legal responsibility may be assigned to producers, operators, or owners for the actions of AI systems and industrial robots, with compensation for resulting damages, while granting these systems rights appropriate to their nature as machines and software, such as the right to register patents, without conferring independent financial standing to avoid legal complications. Human accountability remains paramount, alongside the legal and ethical protection of industrial robots, with engineers and programmers ensuring human safety and preventing liability evasion (Hawamdeh, 2023: 269).

Researchers argue that granting legal personality to industrial robots should be limited and regulated, providing *capacity for rights and duties without capacity for performance*—i.e., recognition of certain rights and obligations without enabling full legal actions. Responsibility should remain with operators or owners, reinforced through mandatory insurance or compensation funds, while avoiding independent financial status to prevent potential legal complications.

4.4. Subsection Two: European Legislative Position on Industrial Robots

The European legislature's position reflects an understanding that the limitation lies not in intelligent robots themselves but in current technological constraints and traditional legal frameworks. To date, robots have not been developed with consciousness or autonomy comparable to humans, and the law remains incapable of granting them full

legal personhood. However, should technological advancement enable robots to think and interact consciously, what risks might arise if they were granted special legal status? (Jahloul & Odeh, 2019: 753)

The concept of “*electronic persons*” remains largely rejected in current legal philosophy and legislation, which continue to regard robots as objects, regardless of technological sophistication. Recognizing such legal status would require fundamental changes to the law, including granting independent financial standing, legal capacity, and civil and criminal liability (Salama, 2014: 39).

If the European Union were to grant full legal personality to intelligent robots, traditional liability theories such as “*guardian of the object*” would no longer apply, undermining conventional responsibility structures. This shift could lead to the emergence of an independent electronic society with rights and obligations, potentially allowing robots to operate beyond human control and raising questions about the effectiveness of law if humans no longer hold sovereignty. It also raises serious concerns regarding labor and economic structures, should robots take over employment, revealing gaps in AI regulation and potentially precipitating critical crises (Al-An, 1993: 267).

The legal consequences of granting electronic personhood to robots could be catastrophic for humans and may render legislation meaningless in the era of advanced AI, which major tech companies aim to achieve. While American legal scholarship attempts to manage this relationship through the “*safe human-machine interaction*” principle, the question remains: is this approach sufficient to address potential risks from robots with independent legal status? (Al-Halaika, 2024: 94)

Scholars conclude that granting legal personality to AI systems represents a risky legal overreach, particularly since these systems have not attained the consciousness or autonomy needed to justify treatment as independent legal entities. Current legal frameworks still treat robots as technical tools, not legal persons. Recognizing AI’s legal personality could undermine the foundations of civil liability and risk creating an independent electronic society that displaces human sovereignty, effectively nullifying law in the face of unrestrained AI capabilities. Consequently, researchers recommend adopting legal provisions that maintain balance, avoid recognizing AI as a legal person, and ensure accountability of responsible humans.

Understanding these trends is essential not only for designers and engineers but also for policymakers, academics, and professionals in technical and administrative fields, as these developments form the foundation of a new industrial revolution with unprecedented opportunities and challenges.

5. Conclusion

In light of the rapid technological developments in artificial intelligence and robotics, researchers contend that granting legal personality to industrial robots—although seemingly a solution to certain practical issues—raises profound legal challenges that touch the very essence of the concept of liability. Accordingly, such recognition must not be absolute, but should instead be subject to strict safeguards that balance technological advancement with the protection of the legal system.

This study has yielded several important findings that reflect the major transformation in the role of industrial robots in the era of accelerated technological progress. Robots are no longer mere static tools operating on pre-programmed commands; they have evolved into intelligent industrial entities capable of interacting with their environment and learning from experience. Modern trends—from collaborative robots to full automation—illustrate how advanced technologies can fundamentally reshape the productive and economic structures of institutions. Integrating robotics with artificial intelligence, machine learning, and the Internet of Things has enabled the creation of industrial environments that are more efficient, flexible, and secure. This integration has enhanced product quality, accelerated production rates, and reduced operational costs. Furthermore, the introduction of augmented and virtual reality technologies has revolutionized training, maintenance, and remote control, paving the way for adaptive and intelligent operational models.

Despite these opportunities, legal and technical challenges remain that require careful awareness and wise legal responses, particularly with regard to regulating the relationship between humans and robots. Against this background, industrial robots can no longer be regarded solely as production tools but as pivotal partners in the future of industry and digital transformation.

Based on the foregoing, the study’s findings and recommendations are as follows:

6. First: Findings

1. Industrial robots cannot be granted full legal personality at present; instead, they should be afforded a restricted and limited legal personality, granting them only the rights and obligations necessary for their functions.
 2. Robots should not be empowered with full legal capacity, as is the case for natural or juridical persons, nor should they be given independent financial standing, so as to avoid potential legal complications.
 3. Legal responsibility must remain with the operator, owner, or programmer, thereby ensuring a human party is accountable for any harm caused by robots.
 4. Although technological progress has made robots more capable of learning and interaction, they are not fully autonomous and require human oversight, particularly in sensitive tasks.
 5. Robots vary greatly in their degree of autonomy, and thus cannot all be regulated uniformly; this requires a precise legal classification of each type.
 6. The study identifies a clear legal vacuum in regulating the human-robot relationship, both nationally and internationally, which complicates the allocation of liability when damages occur.
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7. Second: Recommendations

1. Establish specialized regulatory bodies for artificial intelligence and robotics to oversee their use.
2. Develop a dedicated legal framework to govern the use of industrial robots and specify when and how they may be granted a special and limited legal status.
3. Strengthen international cooperation to formulate agreements or unified legal standards in this field.
4. Adopt legal provisions that preserve balance, prevent the recognition of AI as a full legal person, and ensure accountability of responsible human parties. Suggested provisions include:
 - Article (1): No artificial intelligence system, or non-human entity operating on the basis of machine learning or autonomous computation, shall be granted the status of a natural or juridical person, nor shall it enjoy any independent legal rights or obligations separate from the entity that developed or operates it.
 - Article (2): The developer, owner, or user of an AI system shall bear full civil and criminal liability for actions or damages arising from its operation. Such liability shall be determined according to principles of fault, custody of objects, or product liability, depending on the nature of use and incident.
 - Article (3): Operators or owners of industrial robots that operate partially autonomously shall obtain mandatory insurance with a licensed entity against potential damages. Competent authorities may establish special compensation funds, financed by users and manufacturers, to provide redress where direct responsibility cannot be determined.
 - Article (4): Artificial intelligence shall be deemed a technical tool used by humans, and its actions shall produce no direct legal effect unless approved or ratified by a legally responsible human.
 - Article (5): Under no circumstances shall an AI system or intelligent robot be granted independent financial standing. All financial obligations arising from its use shall remain the responsibility of the natural or juridical persons accountable for it.
 - Article (6): The competent authority shall establish a national registry documenting AI systems, including information about their developers, users, and functions. Prior registration shall be required for any intelligent system deployed in public services or environments affecting safety, privacy, or fundamental rights.
 - Article (7): AI systems must be designed according to the principle of *"safe human-machine interaction,"* ensuring human capability to intervene, stop, or redirect the system at any time. Any attempt to develop fully autonomous systems beyond human control shall constitute a clear violation of public order.

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