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THE BENEFITS OF ROBOTICS IN MANUFACTURING IN THE ERA OF INDUSTRY 4.0: A SYSTEMATIC LITERATURE REVIEW

[1]Renan Rubim de Castro Souza & [2]Cristiane Drebes Pedron

ABSTRACT

Objective: The objective of this study is to identify the expected benefits of adopting robotics technologies in manufacturing.

Originality/Value: This study fills the theoretical gap regarding the benefits of robotics in manufacturing, beyond mere labor substitution, deepening the understanding of the advantages in Industry 4.0 and contributing to the development of future technologies and industrial practices.

Methods: A Systematic Literature Review analyzed thirty-five articles from the Scopus and Web of Science databases, using a structured protocol, resulting in a detailed analysis of the benefits grouped into thematic categories.

Results: The adoption of robotics in manufacturing offers benefits such as increased production efficiency, improved quality, greater competitiveness, ergonomic and safety enhancements, and reduced operational costs. These benefits were grouped into five main categories.

Conclusions: The value of the article lies in providing a comprehensive overview of the benefits of robotics in manufacturing, with implications for both theory and practice, highlighting the importance of public policies that encourage the safe adoption of these technologies.

Keywords: Robotics. Project Management. Benefits Management. Technological Change. Global Challenges.

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[1] Universidade Nove de Julho - UNINOVE, São Paulo, (Brasil). E-mail: renanrubimdecastrosouza@gmail.com Orcid id: https://orcid.org/0009-0007-6170-0173
[2]Universidade Nove de Julho - UNINOVE, São Paulo, (Brasil). E-mail: cdpedron@gmail.com Orcid id: https://orcid.org/0000-0002-9920-3830

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OS BENEFÍCIOS DA ROBÓTICA NA MANUFATURA NA ERA DA INDÚSTRIA 4.0: UMA REVISÃO SISTEMÁTICA DA LITERATURA

RESUMO

Objetivo: O objetivo deste estudo é identificar os benefícios esperados com a adoção de tecnologias de robótica na manufatura.

Originalidade/Valor: Este estudo preenche a lacuna teórica sobre os benefícios da robótica na manufatura, além da substituição de mão de obra, aprofundando a compreensão das vantagens na Indústria 4.0 e contribuindo para o desenvolvimento de futuras tecnologias e práticas industriais.

Métodos: Uma Revisão Sistemática da Literatura analisou 35 artigos das bases Scopus e *Web of Science*, utilizando um protocolo estruturado, resultando em uma análise detalhada dos benefícios em categorias temáticas.

Resultados: A adoção da robótica na manufatura oferece benefícios como aumento na eficiência produtiva, melhoria na qualidade, maior competitividade, melhorias ergonômicas e de segurança, e redução de custos operacionais. Esses benefícios foram agrupados em cinco categorias principais.

Conclusões: O valor do artigo reside em fornecer uma visão abrangente dos benefícios da robótica na manufatura, com implicações para a teoria e a prática, destacando a importância de políticas públicas que incentivem a adoção segura dessas tecnologias.

Palavras-chave: Robótica. Gerenciamento de Projetos. Gerenciamento de benefícios. Mudanças tecnológicas. Desafios globais.

LOS BENEFICIOS DE LA ROBÓTICA EN LA MANUFACTURA EN LA ERA DE LA INDUSTRIA 4.0: UNA REVISIÓN SISTEMÁTICA DE LA LITERATURA

RESUMEN

Objetivo: El objetivo de este estudio es identificar los beneficios esperados con la adopción de tecnologías de robótica en la manufactura.

Originalidad/Valor: Este estudio llena la brecha teórica sobre los beneficios de la robótica en la manufactura, más allá de la sustitución de mano de obra, profundizando en la comprensión de las ventajas en la Industria 4.0 y contribuyendo al desarrollo de futuras tecnologías y prácticas industriales.

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Métodos: Una Revisión Sistemática de la Literatura analizó 35 artículos de las bases Scopus y Web of Science, utilizando un protocolo estructurado, lo que resultó en un análisis detallado de los beneficios agrupados en categorías temáticas.

Resultados: La adopción de la robótica en la manufactura ofrece beneficios como el aumento en la eficiencia productiva, mejora en la calidad, mayor competitividad, mejoras ergonómicas y de seguridad, y reducción de costos operativos. Estos beneficios se agruparon en cinco categorías principales.

Conclusiones: El valor del artículo radica en proporcionar una visión integral de los beneficios de la robótica en la manufactura, con implicaciones tanto para la teoría como para la práctica, destacando la importancia de políticas públicas que incentiven la adopción segura de estas tecnologías.

Palabras clave: Robótica. Gestión de Proyectos. Gestión de Beneficios. Cambio Tecnológico. Desafíos Globales.

1. INTRODUCTION

Very likely, Industry 4.0 (I4.0) will culminate in the so-called “factories of the future,” which will bring innovative production philosophies encompassing digitalization and the reconfiguration of organizational and operational structures (Botha, 2019). It will also entail the need for new human-resources skills and talents, the integration of production with logistics, the restructuring and streamlining of the value chain, and the creation of new business models and revenue streams. In addition, the importance of cybersecurity and compliance with legal regulations still under development will be emphasized (Botha, 2019). The innovations introduced by I4.0 are driving significant changes in production processes, with the trend toward full automation being one of its most striking characteristics. Although robotization began in the 1960s, modern intelligent automation represents a new way of structuring production, data collection, and systems, constituting an advance toward the full digitalization of I4.0 (Anzolin & Andreoni, 2023).

With the growing focus on digitalization and the so-called Fourth Industrial Revolution (4IR), the interaction between digital production technologies and organizational models remains partly unexplored (Anzolin & Andreoni, 2023). Robots, as instruments of automation, are expanding across all areas of society through their integration with Artificial Intelligence (AI) and the Internet of Things (IoT), reshaping every aspect of our daily lives (Wang, Zhou & Chiao, 2023). Furthermore, the adoption of I4.0 amplifies the impact of industrial robots on technological innovation (Lee, Qin & Li, 2022). This leads to intense global competition, high

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labor costs, and market uncertainties, as the manufacturing sector seeks to accelerate innovation, shorten product life cycles, and increase variety, adopting robotization to improve productivity, accuracy, and manufacturing flexibility (Luo & Qiao, 2023).

Organizations need to adopt strategies that prioritize adaptability, reliability, and innovation to position themselves quickly in the global market (Gomes & Romão, 2018). Historically, projects have been fundamental in promoting innovation and change within companies, although the ability to adapt is not universal (Dupont & Eskerod, 2016). Organizations often seek to minimize change efforts through projects, but the expected benefits are not always achieved (Ietto et al., 2022). Despite growing interest in digitalization and the Fourth Industrial Revolution, the interaction between digital production technologies and organizational models remains underexplored (Anzolin & Andreoni, 2023). Even with advances in robotization, little is known about the impacts on worker health and safety (Gihleb et al., 2022).

Digital transformation has the potential to generate approximately 100 billion dollars in additional value over the next decade, spurring the development of new ventures and optimizing existing businesses with digital technologies (Woitsch, 2020). The intelligent robots market is expected to grow from US$ 3.69 billion in 2023 to US$ 19.331 billion by 2032, with a compound annual growth rate (CAGR) of 23.00% (Market Research Future, 2024). However, according to PwC's Brazil Digital Transformation Index 2023, only 12% of companies invest in I4.0, and around 70% of these initiatives, including Robotics, do not meet their objectives (McKinsey, 2020).

There is, therefore, an urgent need for research that explores how organizations can use I4.0 technologies to increase flexibility in manufacturing (Enrique et al., 2022). Studies have focused on job substitution and labor displacement, neglecting other critical factors of robotization (Anzolin & Andreoni, 2023). Moreover, there is a lack of empirical research on the effectiveness of emerging technologies, such as collaborative robots, and on identifying the obstacles and advantages of their implementation (Hwang & Kim, 2021; Schumacher et al., 2022).

In this context, this study aims to identify the expected benefits resulting from the adoption of robotics technologies. Accordingly, this article is organized as follows: Section 2 presents the theoretical framework; Section 3 details the methodology; Section 4 presents the results. The final section provides the concluding remarks.

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2. THEORETICAL FRAMEWORK

The theoretical framework will address issues related to Industry 4.0 and Innovation, the Adoption of Robotics in Manufacturing, and Project Benefits.

2.1 Industry 4.0 and Innovation

Industry 4.0 (I4.0) or the Fourth Industrial Revolution (4IR) introduces new information and communication technologies to production (Shi et al., 2020). I4.0 brings the central concept of horizontal integration in production management, becoming a challenge for integrating objects, services, data, and people (Kanski & Pizon, 2023). I4.0 enabled the technological fusion of Cyber-Physical Systems (CPS), which are composed of collaborative computational components designed to oversee physical entities and manufacturing processes through Internet-based communication (Kumar et al., 2021). In this environment, I4.0 originates from the project related to digital manufacturing, implementing nine technological pillars: systems integration, big data, simulation, additive manufacturing, augmented reality, cloud computing and cybersecurity, autonomous and intelligent robots, and IoT (Rane et al., 2021). With the implementation of these technologies, it has become feasible to convert traditional factories into smart facilities, resulting in value creation for the manufacturing process and improvements in flexibility, continuous expansion of product ranges, and customization (Forcina & Falcone, 2021; Kumar et al., 2021).

Innovation encouraged by automation technology, as a key component of 4IR, has increased significantly in recent years with the rapid development of AI and robots (Wang, Zhou & Chiao, 2023). Based on observations of the Japanese national innovation system, the concept of Innovation Systems emerged and has become popular among academics, practitioners, and policymakers since the early 2000s (Li, Liang, Tell & Xue, 2021). According to the authors, the sectoral system framework was adopted to study innovation and industrial dynamics across a wide range of sectors. In this context, I4.0 changes how business processes are organized and is one of the economic factors that could most benefit from the adoption of these technologies in terms of productivity and global competitiveness (Bettiol, Capestro, Di Maria & Ganau, 2023).

Global market environments have changed rapidly, making innovation increasingly important for both multinational companies and new entrants (Li et al., 2021). This mode of change is specific to each organization’s digital strategy, shaped by the challenge faced, the organization's culture, skills and capabilities, market conditions and innovation needs, as well as the organization's strategy, values, and methods, in addition to stakeholder and partner involvement (Woitsch, 2020). Thus, the current development of 4IR technologies such as AI, cloud computing, additive manufacturing, advanced robotics, and IoT is reshaping existing sectors, bringing opportunities and challenges for companies (Li et al., 2021; Wang, Zhou & Chiao, 2023).

I4.0 constitutes a strategic framework aimed at creating advanced and automated manufacturing systems, symbolizing a new level in the manufacturing industry that involves driving intelligent industrial evolution through the use of data and digital technology (Lee, Qin & Li, 2022). The term I4.0 originated at the "Hannover 2011" fair, the name of a joint initiative designed to strengthen the competitiveness of German industry and coined by three engineers: Kagermann, Wahlster, and Lukas (Obermayer, Csizmadia, Hargitai & Kigyós, 2020). Thus, the concept of I4.0 was born as a more comprehensive definition of cyber-physical systems as a combination of digital tools and physical machines (Bettiol et al., 2023).

As a result of rapidly changing technological and market environments, governments in different countries have formulated policies to address new challenges in the I4.0 era (Li et al., 2021). The challenge is to find appropriate methods, instruments, and tools that support organizations during phases of change (Woitsch, 2020). For example, the U.S. government launched advanced manufacturing initiatives to increase the country's competitiveness, and in China, the State Council released a strategic plan called "Made in China 2025" (Li et al., 2021). While some adopt more holistic approaches, focusing on overcoming social and environmental challenges through innovations, Japan's "Society 5.0" stands out, emphasizing harmony between economic development and social issues in an era of integration between physical and digital spaces (Li et al., 2021).

The future of the manufacturing industry will be defined and guided by I4.0, supported by digitalization, Industrial IoT, cyber-physical systems, hyper-connectivity, and the use and analysis of large amounts of data, rapidly driving new demands for innovation in the sector (Botha, 2019). Digital transformation is a global megatrend triggered by the evolution of digital technology, which has the potential for every organization to optimize its business through digital innovation or disruption (Woitsch, 2020). According to the authors, the challenge for each organization is to identify and tailor the appropriate digital innovation. In this context, I4.0 and smart manufacturing significantly promote the widespread application of industrial robots (Lee, Qin & Li, 2022).

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Robots, as automation tools, are infiltrating every facet of society as they are integrated with AI and IoT, transforming every aspect of our daily routines (Wang, Zhou & Chiao, 2023). In addition, the implementation of I4.0 favors the effects of industrial robots on technological innovation (Lee, Qin & Li, 2022). Innovation driven by robots and robotic technologies may seem inaccessible at first, but its origins are complex and often overlook unconventional contributions (Wang, Zhou & Chiao, 2023). Thus, Martin et al. (2022) emphasize the need to adopt robotics in the manufacturing sector, aiming for flexibility and the optimization of production processes.

2.2 Adoption of Robotics in Manufacturing

Innovation in robotics entails the combination and flexibility of production systems, incorporating everything from automated equipment and autonomous robots to collaborative machines (Bettiol et al., 2021). These systems incorporate robots interconnected with various digital technologies such as sensors, AI, machine learning, IoT, cloud computing, big data analytics, and 3D printing (Bettiol et al., 2021). These technological innovations are predominantly applied to production processes due to their impact on efficiency, productivity, and job creation (Bettiol et al., 2021).

Robots are taking on a growing role in everyday life, impacting social and professional spheres by performing a wide range of activities in homes and workplaces (Leenes et al., 2017). They are also involved in the operation of autonomous vehicles and the enhancement of public transportation systems (Leenes et al., 2017). However, as the field of robotics has expanded and intertwined with other technologies, it has become increasingly challenging to establish a widely accepted definition of the term "robot" (Leenes et al., 2017).

Progress in robotics has resulted in the creation of intelligent robots, also known as "smart robots" (Westerlund, 2020). According to the author, these are autonomous AI systems that can collaborate with humans, learning from their operational environment, experiences, and feedback from human behavior in human–machine interaction. This learning capability aims to continuously improve the performance and capabilities of these intelligent robots (Westerlund, 2020). Westerlund (2020) argues that a robot's appearance is less important than ease of communication, training to perform specific tasks, and effectiveness in task execution.

There are several ways to classify robots, with different conceptual typologies that consider the robot's function and application domain, level of anthropomorphism, the purpose or task of its operation, its ability to adapt to the environment, and the degree of cognition and

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affective resources of the robot (Westerlund, 2020). Leenes et al. (2017) propose that robots may be classified based on their autonomy, function, operating environment, and interactions within human–machine interaction.

Assessing the impact of adopting industrial robotics on business is becoming increasingly prominent in the current landscape of digital transformation (Ballestar, Díaz-Chao, Sainz & Torrent-Sellens, 2021). In the face of intense global competition, high labor costs, and market uncertainties, the manufacturing industry seeks to accelerate innovation, shorten product life cycles, and broaden product variety, resorting to robotization to increase productivity, accuracy, and flexibility (Luo & Qiao, 2023). Innovative firms adopt proactive strategies, including launching new products, improving quality, expanding capacity, and investing in innovative processes, taking the lead in technological and process adoption (Ballestar et al., 2021).

Given growing customer demand, manufacturing companies are adopting robotic systems due to their efficiency, quality, and ability to operate for prolonged periods (Zheng et al., 2023). In this context, in today's competitive environment, industries constantly use robots to perform various tasks because they are more economical and execute programmed tasks with greater precision in less time compared to humans (Komal, 2020).

Industrial robots are increasingly used to perform tasks traditionally assigned to humans (Jia, Yang & Zhang, 2023). Initially developed as automation technology to free workers from dirty, dangerous, and demanding tasks, robots have become indispensable in production (Wang, Zhou & Chiao, 2023). According to the authors, robots enable companies to adopt cleaner production, reducing negative impacts on humans and the environment, lowering energy and material consumption, and making the production process more efficient. Robotic manufacturing systems have proven to be an effective solution for modern manufacturing industries to cope with growing customer demands and market competition (Zheng et al., 2023).

Industrial robots are fundamental to digitalization and the intelligent revolution, making the economic and social impacts resulting from their use popular topics in the field (Lee, Qin & Li, 2022). Management recognizes that technological evolution differs across organizations, with the adoption and implementation of new technologies influenced by firms' ability to capitalize on technological value opportunities through organizational change (Anzolin & Andreoni, 2023). In this context, robots can perform tasks that include welding, painting, assembly, handling, and packaging with greater speed and accuracy, operating in high-intensity production environments that are hazardous or toxic to humans (Luo & Qiao, 2023).

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By adopting a customized design approach, involving users in the initial architectural definition phase can connect their needs with the detailed design, minimizing iterations due to discrepancies between the design and user expectations (Zheng et al., 2023). According to systems engineering principles, the configuration design concept establishes a design process that integrates a set of predefined components with specific forms of connection (Mittal & Frayman, 1989; Zheng et al., 2023). Within this paradigm, different design approaches for robotic manufacturing systems have been proposed (Mittal & Frayman, 1989; Zheng et al., 2023). The co-design and joint co-creation of robotic systems, together with the development of automated solutions for the industrial sector, have experienced accelerated growth in development efforts in recent years (El Souri & Gao, 2022).

Fernandes and O'Sullivan (2021) demonstrated that many related programs and projects do not achieve their potential benefits primarily because they are not aligned with organizational strategy. Recognizing the benefits of innovation, visionary leadership as well as people, structures, and values are identified as crucial elements that influence an organization's ability to leverage them (Ashurst, Freer, Ekdahl & Gibbons, 2012). In collaborative and industrial robotics projects, research and development, together with the implementation of technical solutions, have brought significant gains, offering companies of various sizes cost–benefit justifications and an improved understanding of the technical requirements for their adoption in manufacturing (El Souri & Gao, 2022).

2.3 Project Benefits

A project represents a bounded effort created to deliver a unique product or service, following a predetermined schedule and budget, with the aim of solving issues or meeting social demands (Samset, 2009). Although Project Management (PM) is widely known today, historical evidence such as the pyramids of Giza and the Colosseum shows that this practice has been applied for many centuries (Marnewick & Marnewick, 2019). According to the authors, the second period of PM began in the late 1950s with the introduction of the critical path, the third period occurred in the 1980s and 1990s with the advent of personal computers, and the fourth period has continued to the present, driven by additional technologies introduced.

PM encompasses the responsibility to organize, implement, and oversee all tasks required to meet project goals while respecting constraints of schedule, budget, quality, and available resources (Turner & Müller, 2003). There is a clear trend toward implementing projects geared to I4.0, playing a relevant role and impacting different areas (Farina & Fontana, 2021). In this context, competencies in appropriate technical and behavioral aspects for operating in environments of rapid change, volatility, and elevated risks are demanded by new technologies and digital strategies (Gonçalves et al., 2023).

According to Gonçalves et al. (2023), not all PM practices and approaches are considered adequate, which makes it necessary to examine existing methods with a focus on new technologies in order to recommend contributions and adapt them to the diversity of projects that require different management practices. In the future, it is possible that most project managers will become digital project managers, which underscores the importance of understanding challenges and benefits as well as developing digital competencies for both individuals and organizations (Wu, 2021). In this environment of rapid and disruptive change are projects involving enabling technologies such as advanced robotics, computing technologies, automation, and other innovations (Vido et al., 2020).

Project management has shown advances aligned with the dimensions of the iron triangle scope, cost, and time although it has been less effective in achieving the expected project benefits (Zwikael, Chih & Meredith, 2018). According to Aubry, Boukri and Sergi (2021), benefits management has emerged as a popular practice, even though its implementation and operationalization in companies face significant challenges. Aubry, Boukri and Sergi (2021) highlighted the complexity of defining benefits given the variety of interpretations of the term. In today's business context characterized by continuous change, organizations must adapt and be able to navigate these transformations to ensure their survival and growth (Gomes & Romão, 2018). This implies adopting strategies that ensure rapid insertion into the global market, emphasizing flexibility, reliability, and innovation in products and services (Gomes & Romão, 2018).

Organizations must launch transformation projects and adapt to inevitable and challenging changes to achieve the expected benefits of new initiatives (Dupont & Eskerod, 2016). The capacity to deliver and absorb change, however, is not always present, even though many organizations have an impetus for change (Dupont & Eskerod, 2016). Thus, innovation plays a basic strategic role for many companies (Ashurst, Freer, Ekdahl & Gibbons, 2012). Historically, projects are recognized as effective means to generate change and novelty within organizations (Dupont & Eskerod, 2016). The research literature reporting the impact of organizational project benefits management is quite extensive and quite fragmented, with many

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studies addressing pre adoption issues and many more examining issues during and after the adoption of Organizational Project Benefits Management (Hamidi, 2017).

Given that there is no consensus among researchers, benefits management is defined as a management process concerned with benefits that spans all stages of a project from investment decisions to project delivery through to the realization of benefits (Aubry, Boukri & Sergi, 2021). The authors chose this comprehensive conception because it allows a broad investigation of all activities related to benefits management without being limited to specific stages or technical aspects (Aubry, Boukri & Sergi, 2021). In this context, organizations currently face the challenge of shifting from product delivery to the generation of value and benefits (Gomes & Romão, 2018).

Understanding benefits management is essential because benefits arise from business transformations and are defined by the difference between the desired state and the current state (Hamidi, 2017). Project benefits are divided into target benefits, predefined objectives set by the funder to be achieved with the project investment, and incidental benefits, which arise spontaneously during project execution (Zwikael, Chih & Meredith, 2018). Target benefits such as the reduction of operating costs are important for investment decisions, provide clarity in project management, and consequently stimulate improvements in organizational and project performance in the long term (Zwikael, Chih & Meredith, 2018).

Dupont and Eskerod (2016) define project benefits as streams of value that arise from a project. Because benefits occasionally emerge from the adoption of a new technology, the introduction of a benefits realization program is increasingly seen as an important mechanism to proactively manage new initiatives (Doherty, Ashurst & Peppard, 2012). Considering that projects are launched as a means to achieve specific strategic goals, they are expected to support the organization's business performance (Aubry, Boukri & Sergi, 2021). Research into the success of technology application in organizations is important given the high incidence of failure with respect to information systems projects (Clarke & Doherty, 2004).

3. METHODOLOGY

This research was conducted through a systematic literature review (SLR) to identify the benefits expected from the adoption of robotics technologies. Academic studies on the incorporation of robots have focused mainly on job substitution and the subsequent impact on labor displacement as the primary driving force of robotization, overlooking other potentially fundamental factors

(Anzolin & Andreoni, 2023). In this context, it is important to identify the benefits arising from the adoption of robotics projects.

The SLR stands out as a replicable scientific approach, distinguishing it from other forms of literature review, such as the narrative review. This method narrows the theoretical scope by clearly defining the constructs analyzed, thereby focusing on findings from systematized research (Kanski & Pizon, 2023; Wang et al., 2023; Correa et al., 2023; Pollock & Berge, 2018).

As suggested by Pollock and Berge (2018), this SLR adopted a protocol with six key steps: (1) clarify goals and objectives, (2) find relevant studies, (3) collect data, (4) assess study quality, (5) synthesize evidence, (6) interpret findings, as detailed in Figure 1.

The phases and activities presented here aim to ensure rigor, robustness, and transparency in this type of research and to guarantee its credibility. In this context, the first phase of this study was motivated by the following question: What are the benefits of technological changes resulting from robotics in the manufacturing sector?

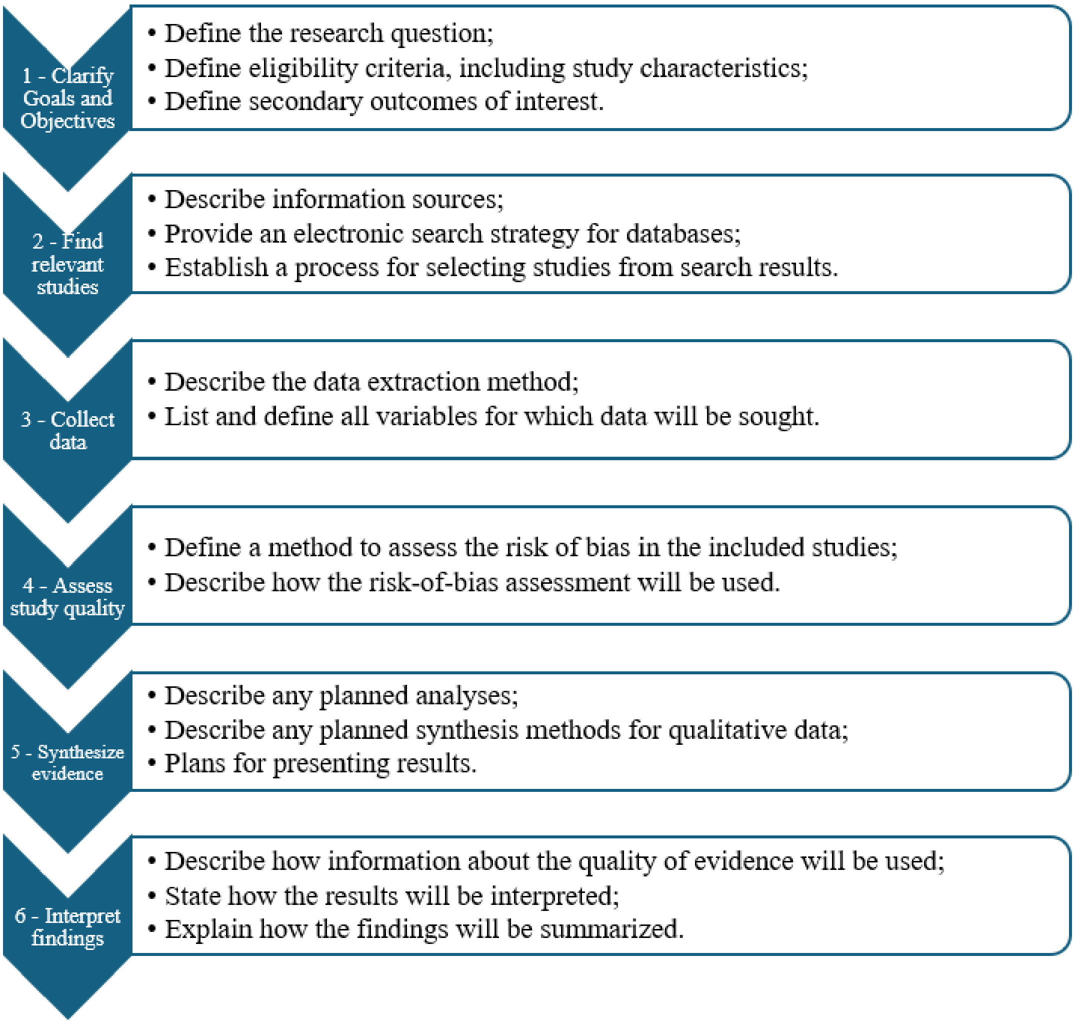

Figure 1. Detailed SLR protocol
Source: Adapted from Pollock and Berge (2018)

The research was conducted using the Scopus and Web of Science (WoS) databases, as they are currently the leading abstract and citation databases, covering major scientific journals across different fields of knowledge (Correa et al., 2023). In the initial protocol, the search employed the keywords "project*" and "robot*." In this context, the search string used was ((manufact* OR industr* OR factor*) AND robot* AND (project* OR adopt*)). It is important to show that the Boolean operator asterisk was used so as not to limit the search or exclude relevant articles. Thus, project* allows retrieving articles containing the words projects, project management, among others. The word "adoption" (adopt in English) was not used as a synonym for "project," but rather in the context that innovative technologies often use this word to refer to their implementation.

The choice of keywords followed criteria based on their relevance and breadth to answer the research question and to ensure the identification of pertinent primary studies, as recommended by Pollock and Berg (2018). A combination of general and specific terms, such as "robot*" and "project*," was used to include variations related to the main topic, aligning with the need to cover a broad and representative body of evidence. The approach included Boolean operators and the use of the asterisk to ensure that different forms and contexts were covered, minimizing exclusion biases and broadening the generalizability of the results.

The search was conducted in December 2023, accessing the Scopus and WoS databases. To ensure consistency, the same criteria and filters were applied to both databases, focusing exclusively on scientific articles and discarding books and other types of publications. Specifically, the administration and business filter was selected, a field that encompasses project management. Articles published between 2018 and 2023 were included to capture research on innovative and disruptive technologies, which are of particular interest in this study. In addition, publications originating from conferences were also considered, given the current relevance of the topic addressed.

The search returned a total of 6,469 relevant articles in the WoS database, and with the same search criteria and filters, 16,319 articles in the Scopus database. Thus, totaling 22,788 selected articles when combining the two databases. In this context, the online analysis platform called Rayyan was used to merge and subsequently remove duplicate articles or those that could not be extracted. It was possible to narrow down to a total of 712 articles. According to Pollock and Berge (2018), we can verify the procedure exemplified in Figure 2.

Still using Rayyan, screening was performed based on title and abstract analysis in order to eliminate articles irrelevant to this research. This four-step construction flow follows the protocol of Pollock and Berge (2018). Subsequently, eligibility criteria were applied to the set of articles, allowing exclusion or inclusion according to the main question of the SLR.

The inclusion criteria determined were: (1) articles associated with projects or the adoption of robotics or I4.0 in the manufacturing environment, or (2) industrial and advanced robots (collaborative and autonomous mobile), or (3) articles associated with Benefits Management and project benefits. To be retained, these criteria may appear with theoretical definition, model, or case studies. Next, the exclusion criterion was applied: articles associated with social robots, medical services, robotic process automation (RPA), educational contexts, automated guided vehicles (AGV), and the construction, medical, hospitality, and agriculture sectors.

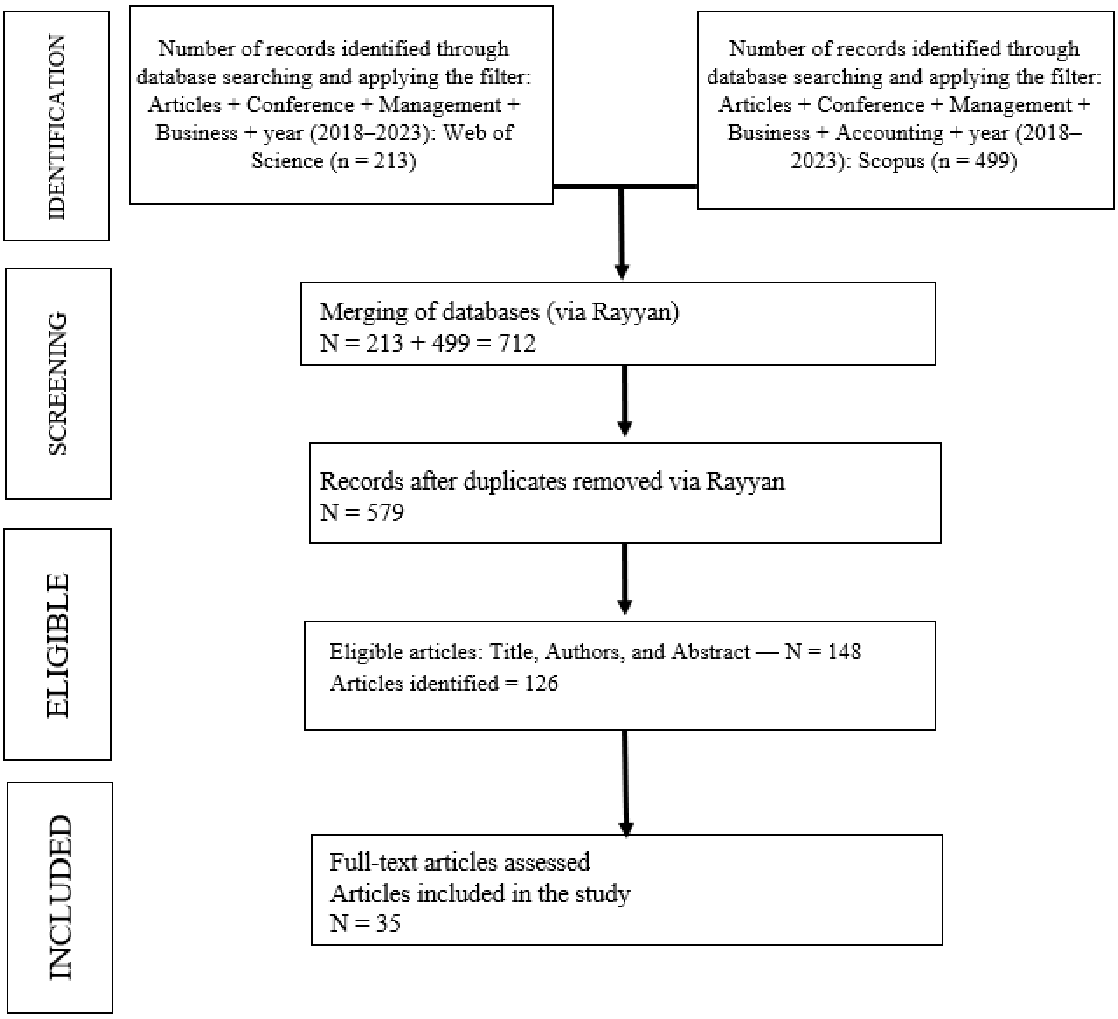

Figure 2. Search flow diagram
Source: Adapted from Pollock and Berge (2018)

A total of 579 articles were identified in the SLR and underwent title and abstract screening. From these, 148 articles were selected and subsequently exported to a Microsoft Excel spreadsheet. In this dataset, 126 articles were found to have the full text available for consultation. After a complete reading, 35 articles were selected as corresponding to the central theme of the research.

4. RESULTS

This section presents the results of the analyses conducted in the SLR.

4.1 Contextualization

This section presents the contextualization, which helps create a frame of reference that facilitates the understanding and interpretation of information. This enables a more detailed and in-depth analysis of the topic.

4.1.1 Frequency of journals or conferences

Initially, a descriptive analysis of the data collected from the articles or conferences is presented. When examining the most frequent sources in the SLR, as shown in Figure 3, the conference Advances in Transdisciplinary Engineering stands out with six papers. The journals Labour Economics, Technology in Society, International Journal of Production Research, IEEE Transactions on Engineering Management, and Journal of Manufacturing Technology Management each presented two articles.

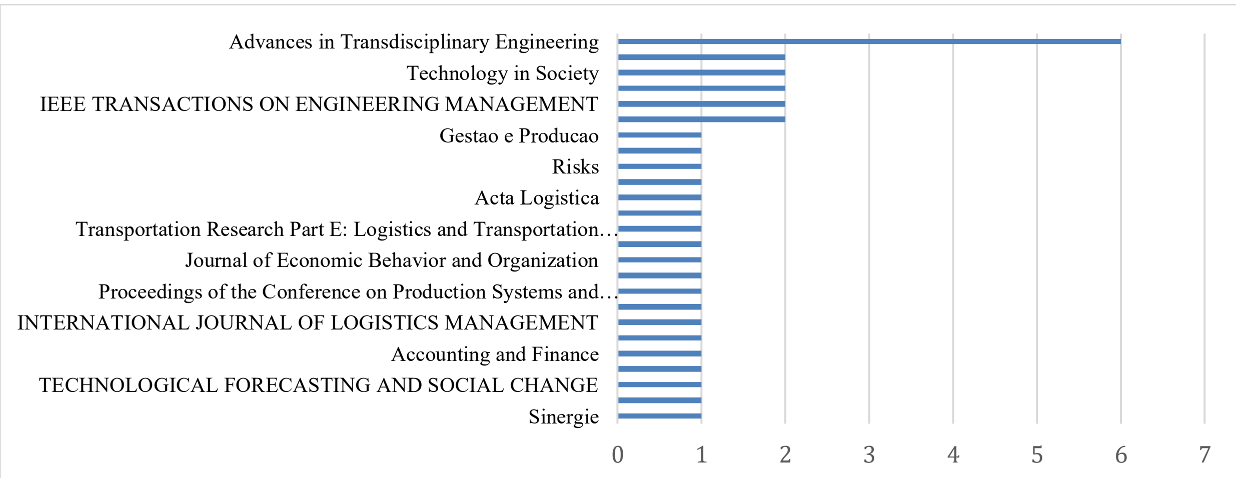

Figure 3. Total articles published per period in the SLR
Source: Prepared by the authors

4.1.2 Frequency of publications per year

The field of robotics has shown an upward trend in research on its benefits, as revealed by an SLR covering 2018 to 2023. In 2018, the base was incipient, with no standout articles. However, by 2019 there was slight growth, with two articles. The year 2020 marked a considerable increase, with five publications, reflecting growing interest in the area. In 2021, seven studies deepened the understanding of the benefits of robotics, and in 2022 the number jumped to ten. Finally, 2023 maintained the growth trajectory, totaling eleven relevant articles. This progression highlights robotics as a fertile and continually evolving field, as shown in Figure 4.

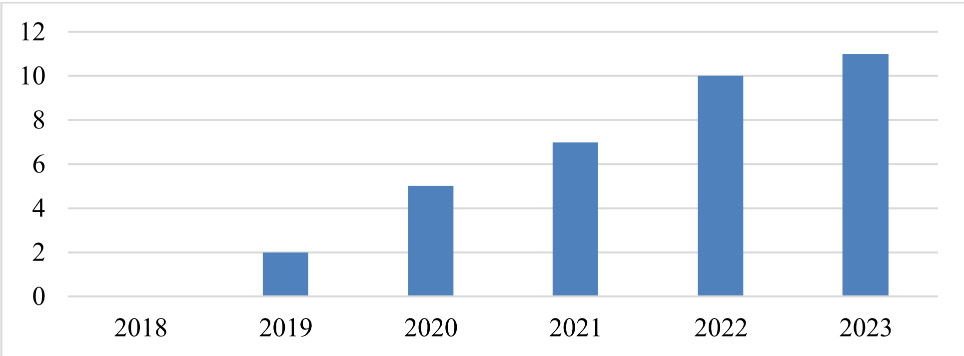

Figure 4. Total number of articles published per year
Source: Prepared by the authors

4.1.3 Author frequency

When examining the most frequent authors in the SLR, it is notable that the 35 articles included in the study involve 114 distinct authors, each appearing with only one publication. The authors Martin, Sharma, Wang, Yang, and Zanfei each have two publications identified in the SLR, as shown in Figure 5. Meanwhile, Anzolin, Gao, Le, and Andreoni stand out with three publications each in the same review. This distribution indicates a significant contribution from these authors to the field, reflecting slightly higher productivity.

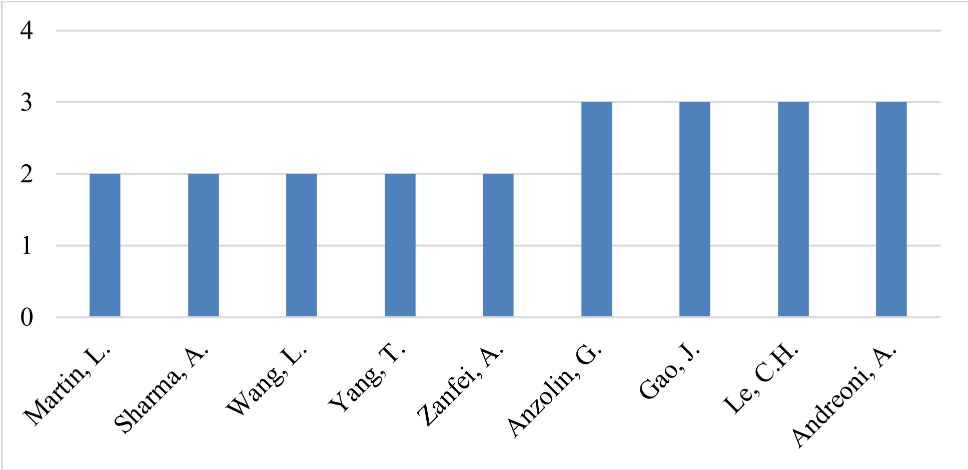

Figure 5. Total number of articles published per author
Source: Prepared by the authors

4.1.4 Frequency of study types

Table 1 presents a distribution of the study types identified in this SLR. Secondary data analysis predominates with a total of twelve studies, indicating a preference for methods that reuse previously collected data for new analyses. Case studies are also significant, totaling seven occurrences, reflecting the importance of in-depth investigations in specific contexts. Mixed-methods studies represent an integrative approach and account for four instances, combining various methodologies: SLR and secondary data analysis; experimental study and interviews; secondary data analysis and exploratory study; and case study and secondary data analysis. Experimental studies and exploratory studies have the same number of applications, with four each, showing a balance between the search for causal evidence and the exploration of new phenomena. Surveys appear less frequently, with three studies, while SLR is the least used, with only one study recorded.

Table 1: Applied study type

Study Type	Quantity
Surveys	3
Secondary data analysis	12
Case study	7
Experimental study	4
Exploratory study	4
SLR	1
Mixed-methods studies	4

Source: Prepared by the authors

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4.1.5 Frequency of research methodology

Table 2 shows a clear preference for the quantitative approach, with a total of nineteen occurrences, standing out as the most adopted methodology in this set of studies. Qualitative research follows with ten instances, indicating significant use but on a smaller scale compared to the quantitative approach. Finally, the mixed approach, which combines both qualitative and quantitative elements, appears six times, suggesting that a considerable share of researchers choose a methodology that integrates the advantages of both approaches to enrich data analysis and understanding.

Table 2: Applied research methodology

Research Methodology	Quantity
Qualitative	10
Quantitative	19
Mixed	6

Source: Prepared by the authors

4.2 Benefits of Robotics

In this section, the benefits identified in the SLR studies were examined. The SLR encompassed the analysis of thirty-five articles and resulted in the identification of one hundred and twenty-eight benefits related to the focus area, as shown in Table 3.

Table 3: Frequency of benefits

Grouping	Identified benefits	Frequency	TOTAL
Market dynamism and competitiveness	Improved competitiveness	11	16
	Rapid transformation and innovation	5	
Increased profitability	Increased profitability	1	1
Productivity enhancement	Increased production efficiency	27	48
	Increased production flexibility	9	
	Increased productivity	12	
Operational efficiency and optimization	Reduction of operating costs	15	20
	Reduction of manufacturing errors	3	
	Time reduction	2	
Quality improvement	Improved product quality	11	19
	Greater manufacturing accuracy	6	
	Product improvements	2	
Human and sustainable advances in industry	Ergonomic improvements and worker safety	12	24
	Improved environmental sustainability	2	
	Better utilization of the workforce	9	
	Increased knowledge	1	

Source: Prepared by the authors

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These benefits were carefully consolidated into fourteen main types, which were subsequently grouped into five categories. This structuring provides a clear view of the distribution and recurrence of the benefits discussed in the articles.

4.2.1 Operational Efficiency and Productivity

The adoption of robotics in manufacturing has proven essential for boosting companies' operational efficiency and productivity, signaling a significant evolution in how products are made. It is possible not only to increase production efficiency and productivity but also to optimize workforce utilization and enhance production flexibility, quickly adapting to changes in demand and new market trends.

The integration of robots into manufacturing processes increases production efficiency by minimizing operational inefficiencies (Anzolin, Andreoni & Zanfei, 2022). Robotic systems can perform complex tasks with high precision and consistency, reducing production cycle time and the errors associated with manual work (Yang et al., 2021). This precision results in improved product quality (Sharma, 2023) while also decreasing material waste, contributing to a more sustainable and economically viable operation (Wang, Zhou & Chiao, 2023). The adoption of an industrial robot is a technology-oriented emerging solution that improves production efficiency and product quality while reducing labor costs and the operator's ergonomic load (Wang et al., 2023).

With the ability to operate continuously, robots provide a substantial increase in productivity (Verma & Singh, 2022). Unlike human workers, who require breaks and are subject to performance variability, robots maintain a steady work pace, enabling faster and higher-volume production (Zheng et al., 2023; Verma & Singh, 2022). This rise in productivity allows companies to meet large market demands in shorter timeframes, an important competitive differentiator in the current landscape. In this context, growth in productivity and operational efficiency can be more significant for large firms, which benefit from economies of scale when adopting robots (Zhang, Zhang & Wu, 2023).

Automation frees workers from repetitive and potentially hazardous tasks, allowing them to focus on more strategic and creative activities (Verma & Singh, 2022). This not only improves job satisfaction and safety but also increases the added value of the workforce. With proper training, employees can take on roles in supervising and maintaining robotic systems, process improvement, and innovation, thereby increasing the human contribution to the overall

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value of production. This allows human collaborators to focus on higher-value, creative activities (Verma & Singh, 2022), in addition to optimizing engineers' time (Martin et al., 2021).

Robotics provides companies with greater flexibility to adapt their production lines to different products or to quickly adjust production volumes (Čech et al., 2020). Robotic systems can be reprogrammed to perform new tasks with relative ease, enabling companies to respond swiftly to changes in consumer preferences or market fluctuations (Komal, 2020). This flexibility is essential for maintaining competitiveness in an ever-evolving business environment. In this context, the expected benefits include increased flexibility and productivity at tactical, operational, and strategic levels (Verma & Singh, 2022).

4.2.2 Quality

The adoption of robotics in manufacturing has revolutionized the industry, bringing significant improvements in product quality, greater manufacturing precision, and continuous innovation in the products offered. These transformations not only optimize production processes but also raise the standard of quality and efficiency, positively reflecting on customer satisfaction and companies' market competitiveness (Anzolin, Andreoni & Zanfei, 2022). The integration of robots into manufacturing processes has a direct impact on the quality of manufactured products (Anzolin, Andreoni & Zanfei, 2022). This is due to robots' ability to perform tasks with consistent precision and a reduced margin of error compared to manual work (De Vries, Gentile, Miroudot & Wacker, 2020). In addition, robotics enables real-time automated quality control, ensuring that any deviation from established standards is immediately detected and corrected. As a result, the product exhibits greater uniformity, durability, and compliance with technical specifications, increasing consumer confidence in the brand.

Precision is essential in many sectors of the manufacturing industry, especially those producing high-technology components such as electronics and aerospace. Robots are programmed to perform complex tasks with high precision and repeatability, minimizing human errors and increasing production efficiency (Santiago, de Oliveira Almeida & Dias, 2019). This is particularly beneficial in processes that require great detail or involve delicate materials, where human error can result in significant waste of resources and time. Robotics enhances manufacturing precision by outperforming manual processes, improving

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effectiveness, reducing execution time, and ensuring a more controlled application in line with quality standards (Santiago, de Oliveira Almeida & Dias, 2019).

Beyond improving quality and precision, robotics also fosters an environment conducive to product innovation (Anzolin, Andreoni & Zanfei, 2022). The flexibility and programmability of robots facilitate experimentation and the implementation of new production techniques, enabling companies to develop more complex and customized products without compromising efficiency. This ability to innovate quickly in response to market demands and technological trends ensures that companies maintain a competitive advantage (Luo & Qiao, 2023), offering products that meet or exceed customer expectations in terms of functionality, design, and performance.

4.2.3 Competitiveness and Market

The adoption of robotics in manufacturing has been one of the main drivers of competitiveness and innovation in modern industry (Ballestar et al., 2021). This transformation not only redefines productive paradigms but also elevates companies to new levels of efficiency and excellence, significantly impacting market competitiveness, innovation capacity, and the development of workforce skills (Luo & Qiao, 2023). The integration of robotic systems into production processes offers a substantial competitive advantage by optimizing processes, resulting in faster, more efficient, and lower-cost production (Bettiol et al., 2021).

Producing high-quality goods at competitive prices is crucial in a globalized and highly competitive market. Robotics also enables greater flexibility on the production line, allowing companies to adapt quickly to changes in consumer demand and to introduce new products more nimbly. The benefits include reduced operating costs, increased productivity and efficiency, and an enhanced ability to compete in rapidly changing markets (Fan et al., 2021; Axelson et al., 2020).

Moreover, robotics accelerates the innovation cycle, enabling companies to experiment with new ideas and product concepts more quickly, reducing the time required to move from concept to commercialization. This improves responsiveness to emerging trends and establishes companies as market leaders in innovation. The automation of repetitive tasks frees human resources for higher-value activities such as research and development, new product design, and process improvement (Jia et al., 2023; Wang et al., 2023). Contrary to the perception that robotics replaces human labor, its adoption often raises workforce skills, promoting a more qualified industry and a safer, more ergonomic work environment (Axelson et al., 2020).

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4.2.4 Sustainability and Social Responsibility

The integration of robotics in manufacturing represents a significant advance not only in terms of efficiency and productivity but also with regard to environmental sustainability and social responsibility (Bettiol et al., 2021). The changes required to achieve the benefits of robotics include adapting the work environment and developing more effective health and safety policies to reduce occupational injuries (Yang et al., 2022). Through automation, industries are finding innovative ways to minimize their environmental impact while improving working conditions and employee safety.

The adoption of robotics in manufacturing contributes substantially to environmental sustainability, mainly through energy savings and waste reduction (Wang, Zhou, & Chiao, 2023). Robotic systems are designed to operate with millimetric precision, which reduces raw material waste by ensuring that each process is executed with maximum efficiency. In addition, the ability to operate uninterruptedly and with less need for lighting or climate control compared with environments traditionally occupied by humans can result in a considerable reduction in energy consumption. One of the most significant benefits of robotics in manufacturing is its ability to assume tasks that are physically exhausting, dangerous, or monotonous (De Vries et al., 2020). This not only reduces the risk of work-related injuries but also contributes to a more ergonomic and safer work environment (Yang, Liu, Lu & He, 2022). By delegating high-risk or high-precision operations to robots, companies can minimize workers' exposure to hazardous conditions, such as handling toxic substances, working at great heights, or operating in environments with extreme temperatures (Schumacher et al., 2022). Additionally, robotics enables the implementation of advanced safety systems that continuously monitor working conditions and can intervene automatically to prevent accidents, thereby ensuring greater protection for workers.

4.2.5 Cost Reduction and Optimization

The adoption of robotics in manufacturing is an effective strategy for cost reduction and optimization, positively impacting companies' profitability and financial sustainability. With robotics, there is a significant decrease in production time and in errors common to manual processes, in addition to a reduction in operating costs, which are crucial factors for strengthening market competitiveness (Bettiol et al., 2021; Ballestar et al., 2021).

Robotic systems offer high precision and efficiency, minimizing the time required for manufacturing tasks (Vaher, Mahmood, Otto & Riives, 2021). Unlike human operators, robots operate 24/7 without breaks, accelerating the production cycle and increasing productive capacity. Automation also reduces the likelihood of manufacturing errors, since robots follow precise instructions and perform tasks with greater consistency than manual work (Sharma, 2023). This improves product quality and lowers costs related to rework and raw material waste.

The implementation of robotics also promotes a significant reduction in operating costs (Vaher et al., 2021). The energy efficiency of robots, compared with labor-intensive manual operations, results in substantial savings. In addition, automation enables more effective management of materials and resources, reducing waste and optimizing inventory (Martin et al., 2021). Although the initial investment in robotic technology is high, in the long term the savings generated by lower costs for labor, workplace accidents, leave, and training of new employees contribute to a marked reduction in total operating costs.

5. CONCLUSIONS

This study explored the benefits of implementing robotics in manufacturing, highlighting significant advances in operational efficiency, cost reduction, and product quality improvement. The results indicate that adopting robotics not only optimizes production processes but also fosters innovation and competitiveness in the sector.

The findings contribute to the literature by showing how robotic technology can serve as a vector for industrial transformation, supporting firms in innovation and global competitiveness. In practice, the study suggests that companies incorporating robotic solutions can benefit from substantial gains in productivity and quality, offering a pathway to sustainability and operational excellence. In this context, the research underscores the importance of establishing regulatory frameworks that foster technological innovation while protecting workers' safety and well-being. This point suggests the need for well-structured public policies capable of balancing technological advancement with social and ethical responsibility, ensuring that the benefits of robotics are accessible in a safe and fair manner to all stakeholders.

The study has limitations, including potential publication bias and constraints arising from the research design. The SLR methodology employed is subject to these limitations,

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requiring caution in interpreting the results. Future research should address these limitations through more comprehensive empirical studies.

It is essential to explore the benefits dependency network in the field of robotics, encouraging detailed future research on how these benefits are achieved in this specific domain. This highlights the need to move beyond the prevailing quantitative emphasis, underscoring the importance of in-depth qualitative approaches to understand firms' success in achieving these benefits, particularly in the development and implementation of robotic technologies.

This study underlines the critical importance of robotics in redefining manufacturing paradigms, offering valuable insights for academics, practitioners, and policymakers. The research emphasizes the need for integrated approaches that consider both the benefits and the challenges of adopting robotics, pointing to a future in which technology and innovation advance hand in hand with sustainable development and continuous improvement.

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