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Review

A Framework for Integrating Robotic Process Automation with Artificial Intelligence Applied to Industry 5.0

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Abstract

The transition to Industry 5.0 highlights the growing integration of Robotic Process Automation (RPA) and Artificial Intelligence (AI) in industrial ecosystems. However, adoption remains fragmented, lacking standardized frameworks to align intelligent automation with human-centric principles. While RPA improves operational efficiency and AI enhances cognitive decision-making, challenges such as organizational resistance, interoperability, and ethical governance hinder scalable and sustainable implementation. The envisioned scenario involves seamless RPA-AI integration, fostering human–machine collaboration, operational resilience, and sustainability. Expected outcomes include (1) hyperautomation for efficiency gains, (2) agile, data-driven decision-making, (3) sustainable resource optimization, and (4) an upskilled workforce focusing on innovation. This study proposes a structured five-stage framework for RPA-AI deployment in Industry 5.0, combining automation, cognitive enhancement, and human–machine symbiosis. A systematic literature review (PICO method) identifies gaps and supports the framework's design, validated through operational, human-impact, and sustainability metrics. Incorporating ethical governance and continuous upskilling, the model ensures technological advancement aligns with societal and environmental values. Results demonstrate its potential as a roadmap for responsible digital transformation, balancing efficiency with human-centricity. Future research should focus on empirical validation and sector-specific adaptations.

Keywords: RPA; AI; I5.0; digital transformation; systematic review; sustainability elements

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1. Introduction

The advent of Industry 5.0 signifies a pivotal transformation in industrial operations, highlighting a deeper integration of human expertise with advanced technological systems. At the heart of this evolution lie Robotic Process Automation (RPA) and Artificial Intelligence (AI), which collectively unlock new levels of operational efficiency, adaptability, and cognitive decision-making. While Industry 4.0 laid the groundwork through the widespread automation of production and data exchange technologies, Industry 5.0 builds upon that legacy by fostering a human-centric vision—one in which collaborative robots, intelligent automation systems, and AI-powered analytics enhance productivity while valuing human creativity and oversight [1]. The role of RPA and AI in this new paradigm is both profound and indispensable. RPA automates rule-based, repetitive tasks, significantly reducing operational costs and the incidence of human error, while AI introduces intelligent functionalities such as predictive modeling and contextual decision-making that enable dynamic optimization of processes [2]. These technologies together pave the way for more intelligent and resilient industrial ecosystems. However, despite their transformative potential, their adoption within the framework of Industry 5.0 remains inconsistent and lacks a cohesive structure to guide integration effectively [3].

The convergence of RPA and AI within Industry 5.0 marks a paradigm shift—blending automation with human-centered innovation. RPA involves the deployment of software bots to automate structured, rule-based activities that are typically performed by humans. Unlike traditional physical robots, RPA operates at the digital level, interacting with existing systems to execute tasks such as data entry, invoice processing, and customer service interactions [4]. This form of automation is non-invasive, leveraging current IT infrastructure without requiring fundamental changes [5]; it operates based on rule-based logic [6] and scales efficiently by deploying multiple bots for concurrent task execution [7]. RPA's evolution from rudimentary screen-scraping tools in the early 2000s to advanced platforms capable of handling semi-structured data via machine learning reflects a significant technological leap [8]. The widespread adoption of RPA is largely due to its cost-effectiveness—often achieving operational savings between 30% and 70% [9]—its ability to eliminate errors in repetitive processes [10], and its support for compliance through the generation of audit trails [11].

Technically, RPA is defined as the use of software agents that interface with existing applications through their graphical user interfaces, executing administrative tasks with high precision, speed, and traceability [12]. These agents are typically configured via low-code or no-code development environments, which allow business analysts—not just programmers—to create automation workflows [13]. Operating continuously and scalable on demand, RPA bots reduce operational costs, enhance compliance, minimize human error, and liberate employees to focus on higher-order cognitive tasks [14]. One of RPA's most compelling advantages is its non-intrusive deployment, which allows organizations to automate processes over legacy systems without major system overhauls [15]. As a result, RPA has gained traction across diverse sectors such as finance, healthcare, logistics, education, and government [16].

Understanding RPA's current significance also requires situating it within the broader historical arc of industrial revolutions [17]. These revolutions redefined modes of production, work, and technology adoption. The First Industrial Revolution, occurring between the late 18th and mid-19th centuries, was marked by mechanization through steam engines and mechanical looms. It replaced manual labor with mechanical power, particularly in textile manufacturing, metallurgy, and transport—introducing repetitive but physically automated production processes [18]. The Second Industrial Revolution, spanning the late 19th to early 20th centuries, saw the emergence of electrification, assembly lines, and mass production. This era intensified standardization, specialization, and management systems such as Taylorism and Fordism, with early forms of automation starting to infiltrate organizational processes, although humans remained at the center of operations [19].

The Third Industrial Revolution (1970s to 1990s) introduced digital automation through technologies like computers, programmable logic controllers (PLCs), enterprise resource planning (ERP) systems, and electronic data management. This period ushered in programmable automation, where digital tools began extending automation from manufacturing to administrative and financial domains [20]. Industry 4.0, emerging from

2010 onward, represents the Fourth Industrial Revolution and features the convergence of Internet of Things (IoT), AI, Big Data, cloud computing, and advanced robotics. This environment gave rise to intelligent, interconnected production systems. RPA gained prominence as a practical response to the digitalization of administrative operations, bridging the gap between shop-floor automation and back-office efficiency. Its quick implementation, cost advantages, and compatibility with legacy systems made it a valuable addition [21]. Industry 5.0, the current and future phase, introduces a more inclusive model that prioritizes human–machine collaboration, sustainability, and resilience. In this new framework, RPA evolves into Intelligent Process Automation (IPA), integrating machine learning, natural language processing (NLP), and contextual intelligence [22]. Here, automation transcends operational efficiency to become a driver of workplace well-being, social innovation, and intelligent decision-making [23].

The development of RPA can be broadly categorized into three stages. The initial phase, RPA 1.0, focused on automating simple, rule-bound tasks like data entry and report generation [24]. The second phase, RPA 2.0, introduced concepts of scalability and governance through the establishment of Centers of Excellence (CoEs), standardized orchestration, and the emergence of attended and unattended robots [25]. The current stage, RPA 3.0, also known as Intelligent Automation or Hyperautomation, incorporates AI, optical character recognition (OCR), natural language understanding, and predictive analytics, thereby enabling bots to learn, interpret, and adapt to dynamic contexts. RPA has thus transitioned from an operational tool to a strategic enabler of digital transformation [26].

Far from being a simple automation tool, RPA embodies the digital maturity of organizations aiming to align with the demands of Industry 5.0 [27]. Its trajectory mirrors the evolution of industrial revolutions and positions it centrally in the shift toward more humanistic, resilient, and sustainable models of production [28]. Its applicability spans diverse sectors, including finance for fraud detection and reconciliations [29], healthcare for managing patient records [30], and manufacturing for supply chain visibility [31]. Nonetheless, traditional RPA technologies face limitations in volatile environments, highlighting the necessity of integration with AI to achieve adaptive, intelligent automation [32].

Artificial Intelligence, a field of computer science focused on simulating human cognitive capabilities such as learning, reasoning, perception, and adaptation, has evolved from theoretical beginnings in the mid-20th century to become a cornerstone of contemporary digital transformation [33]. Within Industry 5.0, AI not only represents technological sophistication but also reflects a paradigm shift toward systems that priorities ethical collaboration, efficiency, and sustainability in human–machine interactions [34,35]. Unlike Industry 4.0, which concentrates on automation and efficiency, Industry 5.0 underscores collaborative work between humans and intelligent agents. This collaboration is exemplified through the integration of RPA for operational efficiency and AI for contextual understanding and adaptability [35].

In the context of Industry 5.0, emphasis is placed on human–machine collaboration, where robots and humans share workspaces and responsibilities; on sustainability, as AI algorithms optimize resource usage and RPA reduces paper-based workflows; and on resilience, with decentralized AI-RPA ecosystems enhancing the robustness of supply chains [36]. The synergy between RPA's execution capabilities and AI's cognitive intelligence enables hyperautomation—complete end-to-end optimization of processes such as procurement, logistics, and service delivery [37]. It also facilitates personalized manufacturing, where AI tailors customer experiences and RPA executes bespoke workflows [38]. Furthermore, this integration supports real-time decision-making: for example, AI may forecast equipment failures while RPA executes preventive countermeasures [39]. In smart manufacturing settings, RPA bots collect data from machinery while AI interprets it to predict anomalies, thus reducing downtime [40].

Over recent decades, industrial landscapes have experienced rapid transformation through the digitalization of production processes. Industry 4.0 introduced interconnected systems and automation, driven by technologies such as IoT, Big Data, AI, and cyber–physical systems. However, a new paradigm—Industry 5.0—has emerged across scientific, political, and business domains [41]. Industry 5.0 is more than an extension of its predecessor; it proposes a philosophical realignment of how technology is designed and utilized in industrial contexts. While Industry 4.0 focuses on performance, scalability, and interconnectivity, Industry 5.0 reasserts the human presence at the center of production systems. It champions collaboration between humans and intelligent machines, promoting mass personalization, ecological sustainability, and systemic resilience [42].

Industry 5.0 is defined as a model of industrial development that complements economic and technological advancement with social responsibility and environmental consciousness. Rather than displacing human workers, this paradigm fosters symbiotic collaboration, using technology to empower labor, improve working conditions, and generate meaningful societal impact [43]. It transcends the objective of automation for its own sake and advocates for purposeful industrial renewal, guided by the principles of inclusivity, diversity, and ethical responsibility.

The Central Research Question (RQ) and Hypotheses (H) of this study were appropriately formulated as follows:

RQ: *How can the integration of Robotic Process Automation (RPA) and Artificial Intelligence (AI) in Industry 5.0 optimize industrial processes, promoting operational efficiency, human–machine collaboration, and sustainable practices, and what are the main challenges and opportunities associated with their implementation?*

H1: *The integration of RPA and AI in Industry 5.0 contexts significantly improves the operational efficiency of industrial processes.*

H2: *The joint adoption of RPA and AI fosters effective collaboration between humans and automated systems, promoting more sustainable industrial practices.*

By providing a clear methodological roadmap, this study contributes to both academic discourse and industrial practice, offering actionable insights for companies navigating the transition to intelligent automation. The remainder of this paper is structured as follows: Section 2 presents a systematic literature review to analyze current research trends and gaps. Section 3 details the development of the proposed framework, including its key features and implementation rationale. Section 4 presents a comprehensive analysis of this research and also presents the conclusions.

2. Systematic Literature Review

2.1. Method

The choice of the PICO (Population, Intervention, Comparison, Outcome) methodology to conduct this systematic literature review is justified by its ability to structure the research in a clear, objective, and rigorous manner. The use of this approach allows for a detailed analysis of the central issues of the study, overcoming the limitations of narrative reviews, such as subjectivity and the lack of a systematic framework. The systematic review, in turn, focuses on a well-defined research question, which guides the selection, analysis, and synthesis of relevant studies, thereby providing greater robustness and transparency to the process [43].

In this context, the population defined for this study encompasses organizations and industrial sectors that are implementing, or consider implementing, technologies associated with Industry 5.0, with the goal of promoting intelligent automation practices by integrating technologies such as Robotic Process Automation (RPA) and Artificial Intelligence (AI). The analysis focuses on investigating how these technologies can work in tandem to increase the efficiency, sustainability, and resilience of industrial systems [9].

The intervention considered refers to the application of emerging Industry 5.0 technologies—specifically RPA and AI—to optimize industrial processes, fostering greater productivity and intelligence in decision-making, without compromising the human role. The choice of these technologies stems from the growing academic and industrial interest in exploring how intelligent automation can transform industrial ecosystems, while maintaining a focus on human–machine collaboration. These technologies have the potential to reduce human error, optimize processes, improve efficiency, and drive sustainable innovation in production environments [44].

The comparison will be made between organizations and sectors that actively adopt the integration of RPA and AI into their processes with a human-centric and sustainable vision, and those that, although they may employ some of these technologies, do not integrate them with the same level of commitment in terms of human innovation and operational efficiency. This comparative analysis will be crucial for identifying the differences in the approaches adopted, the outcomes generated, and the impacts incurred, enabling the evaluation of critical factors for the success of effective integration between new technologies and sustainability in industrial environments [44].

The expected outcome of this research is the identification of the main advantages and challenges associated with the implementation of RPA and AI in the contexts of Industry 5.0, as well as an analysis of the impacts of these technologies on the operational and strategic dimensions of organizations. Additionally, this work seeks to characterize the industrial sectors that benefit most from such approaches, generating knowledge that can serve as a foundation for adopting more efficient and sustainable strategies, both for academia and business decision-makers.

The selection of studies included in the review was conducted based on the PICO methodology, using strict inclusion and exclusion criteria. The identification of articles began with a comprehensive bibliographic search, followed by screening by title and abstract, with the aim of finding studies addressing the convergence between RPA, AI, and the principles of Industry 5.0. Studies that did not align with the object of study were excluded, resulting in a final sample of relevant articles that provided significant contributions.

The database used to collect publications was the "B-on" platform, recognized for its breadth and the quality of scientific publications accessible, indexed in systems such as ISI Web of Science and Scopus. This choice ensures the rigor and timeliness of the literature analyzed, providing a solid foundation for the development of systematic review. The B-on platform is an online library that brings together a wide collection of research papers from various academic sources, including the renowned IEEE, ACM, ISI Web of Science and Scopus digital libraries, facilitating access to high-quality scientific publications. This database is recognized for its comprehensiveness and the quality of the scientific articles available. This selection ensures the rigor and timeliness of the literature analyzed, providing a solid basis for the development of systematic reviews. In addition, B-on offers an intuitive interface and advanced search tools, allowing researchers to efficiently locate and access the resources they need for their studies. Digital technologies, including areas such as automation and Artificial Intelligence (AI), have been widely explored by the global academic community, although there are still gaps in specific research on their application and impact. In this context, the B-on library plays a fundamental role, as it offers consolidated access to a vast database of scientific publications from renowned institutions. In this way, the platform contributes significantly to the progress of research in digital technologies, fostering new discoveries.

To undertake the underlying research process, investigators accessed the scientific digital library provided by the Foundation for Science and Technology, focusing on three distinct groups (Group 1, Group 2, and Group 3), as outlined in Table 1.

Table 1. Groups searched through "B-on".

	Research Strings
Group 1	"Robotic Process Automation" OR "RPA" OR "Automation" OR "Process Automation" OR "Intelligent Automation" OR "Digital Workforce" OR "Robots" OR "Software Robots" OR "Automation Technology" OR "Business Process Automation" OR "BPA" OR "Automated Workflows" OR "Cognitive Automation" OR "AI-driven Automation" OR "Automation Tools" OR "RPA Solutions" OR "Automation Platform" OR "Robotic Automation" OR "Automated Processes" OR "Machine Learning Automation" OR "Hyperautomation" OR "Automation Software" OR "RPA Implementation" OR "Business Efficiency Automation" OR "Automation Deployment" OR "RPA Technology" OR "Digital Transformation with RPA" OR "Intelligent Process Automation" OR "Automated Operations" OR "End-to-End Automation"
	AND
Group 2	"Artificial Intelligence" OR "AI" OR "Machine Learning" OR "Deep Learning" OR "Neural Networks" OR "Natural Language Processing" OR "NLP" OR "Computer Vision" OR "AI Algorithms" OR "AI Models" OR "Supervised Learning" OR "Unsupervised Learning" OR "Reinforcement Learning" OR "AI Applications" OR "AI Solutions" OR "Cognitive Computing" OR "AI Automation" OR "AI-driven Insights" OR "AI Robotics" OR "Intelligent Systems" OR "AI for Business" OR "AI in Healthcare" OR "AI in Finance" OR "AI in Manufacturing" OR "AI Technology" OR "Artificial Neural Networks" OR "AI-Powered Systems" OR "Data Science" OR "Predictive Analytics" OR "AI Ethics" OR "AI Governance" OR "AI and Big Data" OR "AI in IoT" OR "AI Chatbots" OR "AI and Automation" OR "AI Research" OR "AI Development" OR "AI Algorithms in Robotics" OR "AI Innovation" OR "AI Integration"
	AND
Group 3	"Industry 5.0" OR "Future of Industry" OR "Humans and Machines" OR "Advanced Automation" OR "Artificial Intelligence" OR "Industrial IoT" OR "Collaborative Robotics" OR "Mass Customization" OR "Advanced Manufacturing Technology" OR "Smart Manufacturing" OR "Intelligent Industry" OR "Digital Transformation" OR "Cyber-Physical Systems" OR "Smart Cities" OR "3D Printing Technology" OR "Industrial Sustainability" OR "Circular Economy" OR "Data Intelligence" OR "Industrial Connectivity" OR "Flexible Automation" OR "Adaptive Manufacturing" OR "5G Technology" OR "Connected Industry" OR "Autonomous Systems" OR "Sustainable Production" OR "Human-AI Collaborative Work" OR "Innovation Culture" OR "Sustainable Transformation" OR "Product Customization"

The research queries were conducted using the "B-on" platform, employing the OR operator to link the title, keywords (KWs), or abstract (AB) within the three specified groups. Subsequently, during the research process, filters were applied based on the acquired publication sets, and the results, in terms of the number of publications, are summarized in Figure 1. The research methodology adopted was the PICO framework (Population, Intervention, Comparison, Outcome), which was selected due to its structured and objective approach in formulating research questions and guiding systematic literature searches. PICO enables the identification of the most relevant studies by clearly defining the essential components of the research focus, thereby increasing the precision and relevance of the search strategy. To ensure transparency and reproducibility of the selection process, the organization of the data—including the screening, inclusion, and exclusion of studies—was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. PRISMA provides a standardized checklist and a flow diagram illustrated in Figure 1 that facilitate a clear and comprehensive presentation of how studies were identified, screened, and selected for inclusion in the review, enhancing both the methodological rigor and the credibility of the findings.

Following the application of the filters, a review was conducted of the titles, keywords, and abstracts of each article to identify those directly relevant to the research. Initially, a total of 4307 articles were retrieved. After the application of the filters, 773 articles remained, of which only 15 were found to be aligned with the research topic.

This systematic literature review was conducted based on the guidelines of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) model, widely recognized for its rigorous structure, transparency, and reproducibility. The choice of the PRISMA methodology is justified by its effectiveness in organizing and clearly presenting systematic reviews, allowing for the documentation of all phases of the process—

from the identification and selection of studies to their final inclusion—in a transparent and replicable manner. This methodological framework proved essential to ensure the reliability of the results obtained, especially in view of the objective of mapping emerging and complex trends, such as the integration of Robotic Process Automation (RPA) and Artificial Intelligence (AI) in the context of Industry 5.0.

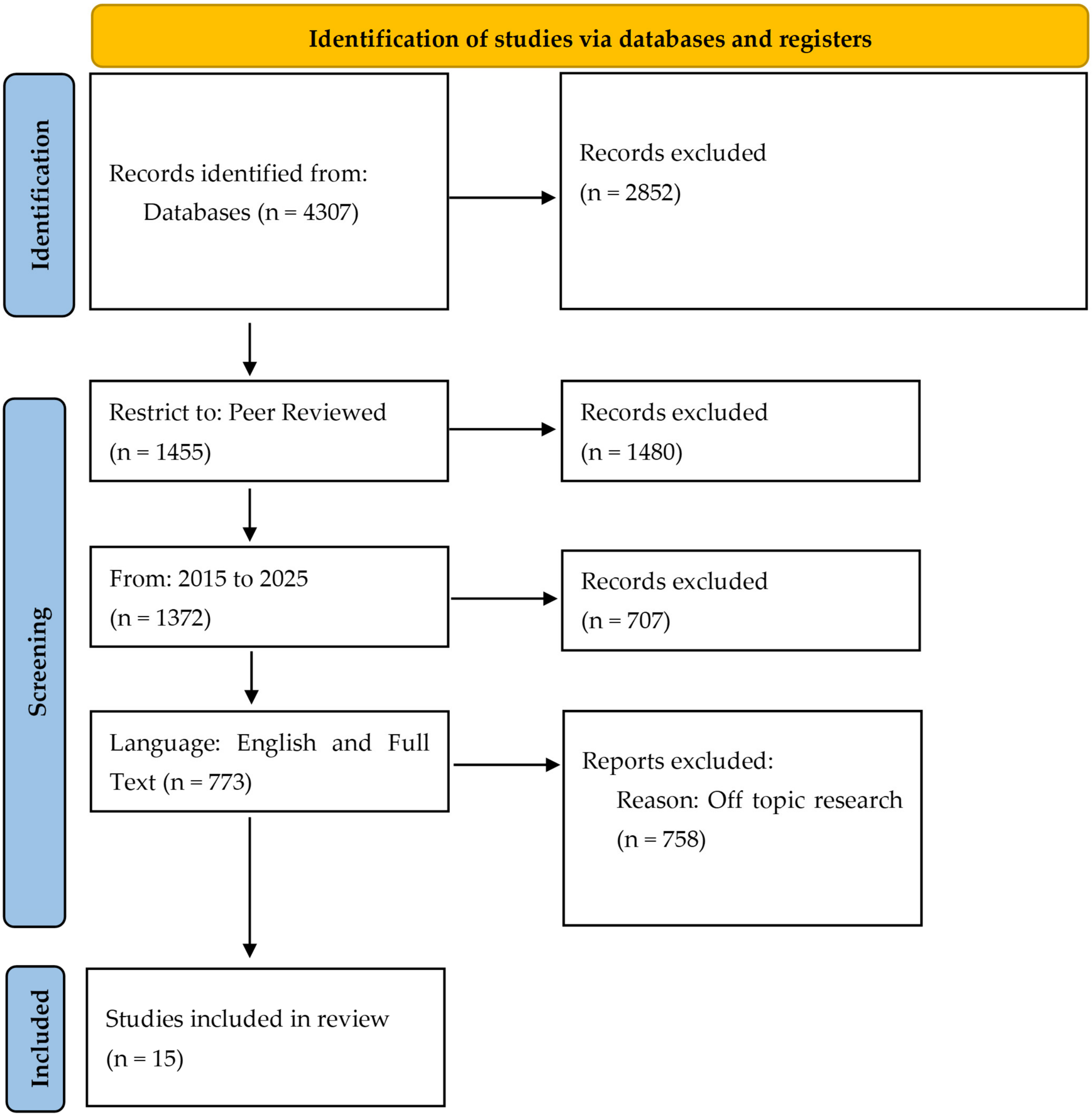

Figure 1. Flow diagram of literature search and respective screening.

In addition, it was decided to complement the PRISMA approach with the PICO (Population, Intervention, Comparison, Outcome) methodology, traditionally applied in the health area, but whose logical structure has been increasingly adopted in engineering, management, and industrial systems studies. The application of PICO in this study was carefully adapted, allowing the research question and the selection criteria for the studies included in the review to be formulated in a clear and systematic manner.

Within the scope of this research, the "Population" component corresponds to the organizations and industrial sectors that are involved in, or show interest in, the adoption of technologies associated with Industry 5.0, with a special focus on intelligent automation. The "Intervention" analyzed refers to the integrated application of RPA and AI as catalysts for efficiency, sustainability, and resilience in industrial processes. The "Comparison" established focused on the distinction between organizations that adopt these technologies with a strategic vision centered on human beings and sustainability, and those that, although they use them, do so in an ad hoc and non-integrated manner. Finally, the "Expected Results" focus on identifying the main benefits, challenges, and impacts—both operational and strategic—arising from the combined adoption of RPA and AI.

This methodological adaptation made it possible to transform an initially broad question about digital transformation in industry into a rigorous, structured, and results-oriented analysis. Although developed in the biomedical context, the PICO method demonstrates, in this study, its flexibility and relevance when properly contextualized in technological and industrial domains. Its use did not constitute a mere methodological transposition, but rather a functional tool, adjusted to the specific objectives of this review.

Thus, the combination of the PRISMA and PICO methodologies provided a solid methodological basis adapted to the multidisciplinary nature of this study. This combination ensures a systematic review with well-defined criteria, a transparent selection process, and a robust analytical focus, giving greater scientific validity to the framework proposal presented for the integration of RPA and AI in the Industry 5.0 paradigm.

2.2. Summary and Analysis of Selected Articles

In this section, the most relevant articles for the topic under study are analyzed. Table 2 shows the identified articles. This table was created to analyze the contributions of each study, based on an exhaustive search in academic databases.

Table 2. Analysis of identified articles.

Article	Industry 5.0 (Principles)	RPA	Collaborative AI	Human-Centricity	Technological Integration (I4.0 → I5.0)	Challenges/Barriers	Practical Applications	Social Values/Sustainability
[45]	X		X	X	X	X	X	X
[46]	X			X	X	X		
[47]	X		X	X	X	X	X	X
[48]	X			X	X	X		X
[49]	X		X	X	X	X	X	X
[50]	X			X	X	X		X
[51]	X		X		X	X	X	X
[52]	X		X					
[53]	X		X	X			X	X
[54]	X		X	X		X		X
[55]		X				X	X	
[56]		X				X	X	
[57]		X				X	X	
[58]		X				X	X	
[59]		X	X				X	

The selected articles were thoroughly reviewed and analyzed to identify recurring themes related to Industry 5.0. These themes were systematically organized into a structured table, where columns represent distinct categories and rows correspond to individual articles, with markings indicating coverage of each theme.

From this analysis, several critical insights emerge. Industry 5.0 is fundamentally characterized by a human-centric approach, where technology is designed to enhance human capabilities rather than replace them. This principle is supported by fluid human–machine collaboration, ensuring that automation complements human decision-making rather than operating in isolation. Additionally, sustainability is embedded throughout the entire life cycle of solutions—from initial design to implementation—reinforcing the need for environmentally and socially responsible innovation. Another key structural element is the use of intuitive interfaces and feedback loops, which ensure continuous adaptation based on human input.

At the foundational level, Robotic Process Automation (RPA) primarily handles repetitive, rule-based tasks. However, the reviewed studies revealed a significant gap: none demonstrated meaningful integration with AI or Industry 5.0 principles. This suggests that RPA, while useful for basic automation, must evolve into a more intelligent framework to support advanced Industry 5.0 applications.

Collaborative and Explainable AI (XAI) plays a pivotal role in bridging this gap. Its applications focus on shared decision-making, particularly in adaptive systems where human oversight remains essential. A strong emphasis is placed on transparency and explainability, ensuring that AI-driven processes are interpretable and trustworthy. This is particularly crucial in human–machine interfaces, where clarity and accountability foster seamless cooperation.

The transition from Industry 4.0 to 5.0 follows a model of progressive technological integration, where iterative advancements lead to more cohesive and adaptive industrial ecosystems. However, this evolution faces several challenges, including cultural resistance to change, a lack of interoperability standards, data security risks, and the need for continuous workforce upskilling. These barriers must be addressed to facilitate widespread adoption.

In practice, energy management, logistics, and flexible manufacturing emerge as the most promising fields for Industry 5.0 applications, given their potential for both operational efficiency and human-centric improvements. Beyond technical implementation, sustainability, ethics, and social inclusion serve as guiding principles, ensuring that technological progress aligns with broader societal benefits.

Now, after analyzing the identified research works and presenting the summary of the results in the table, we move on to the development of the framework.

3. Development of the Framework

3.1. Framework Proposal

The successful implementation of Robotic Process Automation (RPA) and Artificial Intelligence (AI) within Industry 5.0 requires a structured, phased approach that harmonizes automation with human collaboration. This section introduces a novel framework designed to guide organizations in adopting these technologies systematically, addressing both technical and strategic dimensions.

The proposed framework is built upon three foundational pillars:

1. Task Automation (RPA-Driven Efficiency)—Streamlining repetitive, rule-based processes.
2. Cognitive Enhancement (AI-Driven Adaptability)—Enabling predictive and autonomous decision-making.
3. Human–Machine Symbiosis (Industry 5.0 Alignment)—Ensuring collaboration, sustainability, and resilience.

The framework follows a five-stage implementation logic, ensuring seamless integration while mitigating risks (Table 3):

Each stage is supported by key enablers, including workforce upskilling, IT infrastructure readiness, and ethical AI considerations (Figure 2).

The convergence of Robotic Process Automation (RPA) and Artificial Intelligence (AI) in the context of Industry 5.0 requires a systematic methodology that balances automation efficiency, cognitive adaptability, and human-centered collaboration. To meet this need, we propose a structured framework that guides organizations through a continuous, scalable, and risk-mitigated adoption process. This model rests on three interdependent pillars—task automation (RPA) to achieve quick wins, reduce operational costs, and free up people for higher-value activities; cognitive enhancement (AI) to enable predictive analytics, autonomous decision-making, and optimization of complex processes by dealing with unstructured data; and human–machine symbiosis, aligned with Industry 5.0, that promotes employee well-being, sustainability, and ethical governance—and unfolds in five logical steps: process assessment and selection, using mining and interviews to define a priority pipeline; technology stack configuration, integrating RPA tools such as UiPath or Blue Prism with AI models—ensuring interoperability and scalable infrastructure; pilot deployment in a controlled environment to validate performance, ROI, and user insights; enterprise-wide integration, with training on human–robot collaboration (cobots) and assistive AI, supported by change management; and, finally, continuous optimization, with model refinement, bias auditing, and ethical compliance. This framework also connects directly to Industry 5.0 principles by prioritizing human-centricity, sustainability—with optimized processes to reduce waste and energy consumption—resilience through adaptive systems in the face of disruptions, and differentiating itself by offering phased risk mitigation, ethical governance by design, and modular scalability. In this way, we provide a practical and holistic roadmap for organizations to leverage RPA and AI within the human–machine paradigm of Industry 5.0, ensuring that automation brings not only efficiency, but long-term operational and societal value.

Table 3. Five-stage implementation logic of the framework.

1. Process Assessment and Selection
2. Technology Stack Configuration
3. Pilot Deployment and Validation
4. Full-Scale Integration and Human Augmentation
5. Continuous Optimization and Ethical Governance

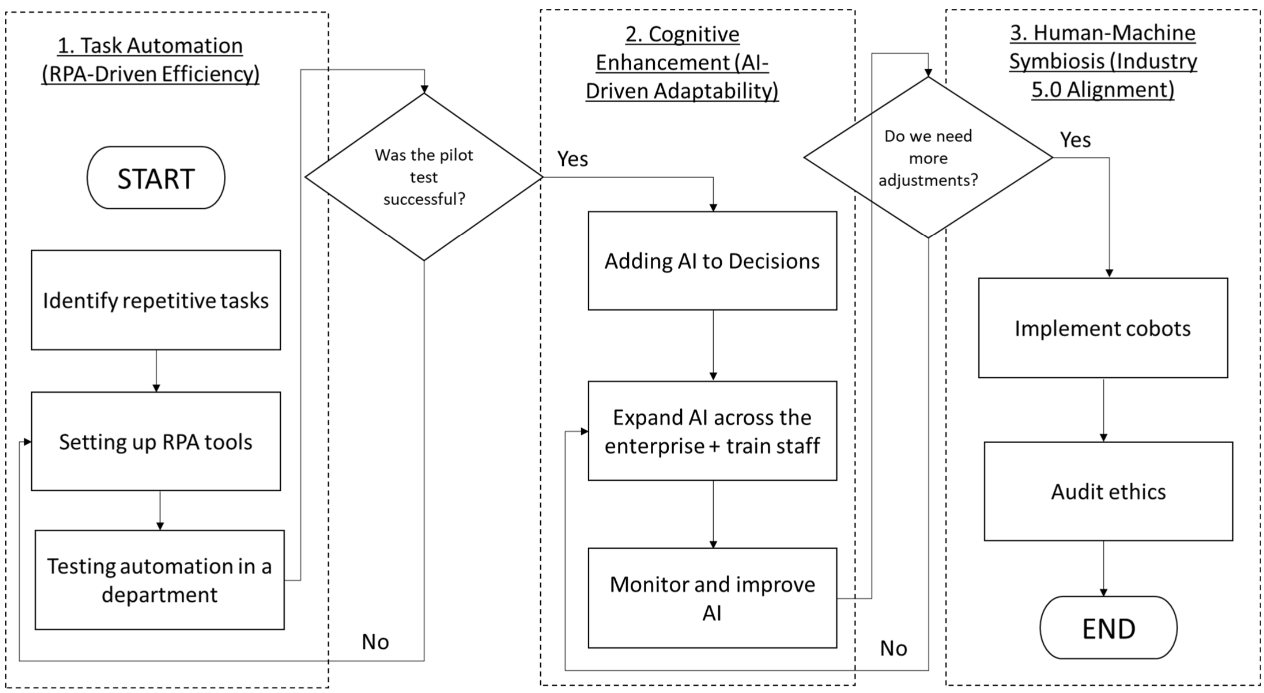

Figure 2. Flow diagram of proposal framework.

3.2. Framework Features

The framework's core features are designed to address the synergistic potential of RPA and AI while aligning with Industry 5.0's human-centric vision.

3.2.1. RPA's Role: Structured Automation for Efficiency

RPA serves as the operational backbone, automating rule-based workflows to reduce manual effort. Its key functions are presented in Table 4.

Table 4. Core RPA features and their alignment with Industry 5.0.

Feature	Purpose	Industry 5.0 Relevance
Non-invasive Automation	Executes tasks without modifying legacy systems.	Ensures smooth transition.
High Scalability	Deploys multiple bots for parallel task execution.	Supports mass customization.
Error Elimination	Reduces human errors in repetitive tasks (e.g., data entry, invoicing).	Enhances operational reliability.
Compliance Adherence	Maintains audit trails for regulatory requirements.	Supports ethical transparency.

However, traditional RPA lacks cognitive flexibility, necessitating AI integration for dynamic decision-making.

3.2.2. AI's Role: Cognitive Augmentation for Adaptability

AI enhances RPA by introducing learning, reasoning, and predictive capabilities, transforming automation into intelligent automation (Table 5).

Table 5. Core AI Features and their alignment with Industry 5.0.

Feature	Purpose	Industry 5.0 Relevance
Predictive Analytics	Forecasts demand, detects anomalies (e.g., predictive maintenance).	Reduces downtime, improves resilience.
Natural Language Processing (NLP)	Enables human–bot interaction (e.g., AI chatbots).	Enhances collaborative interfaces.
Computer Vision	Automates quality inspection via image recognition.	Supports precision manufacturing.
Adaptive Learning	Self-improving algorithms based on real-time data.	Enables continuous optimization.

3.2.3. Industry 5.0 Integration: Human-Centric Automation

The convergence of Robotic Process Automation with Artificial Intelligence must be aligned with the principles of Industry 5.0 where collaborative robots allow humans and bots to work side by side, promoting sustainable automation in which Artificial Intelligence optimizes the use of energy and resources while RPA reduces waste, contributing to resilient systems that rely on decentralized networks, combining AI and RPA to avoid single-point failures. A hybrid governance model is essential to ensure the ethical application of these technologies, guaranteeing human oversight in critical decisions, maintaining control by people, promoting explainable Artificial Intelligence that ensures transparency in automated decisions, and supporting the continuous evolution of workers' skills through reskilling and development programs to prepare them for new roles in the emerging digital ecosystem.

3.2.4. Implementation Roadmap

The framework's five-stage deployment model ensures structured adoption (Table 6).

Table 6. Framework implementation roadmap.

Stage	Key Actions	Outcome
1. Process Assessment	Identify high-impact, rule-based processes for automation.	Priority automation pipeline.
2. Tech Stack Configuration	Select RPA tools (e.g., UiPath, Blue Prism) and AI models (e.g., TensorFlow).	Interoperable system design.
3. Pilot Deployment	Test automation in controlled environments (e.g., finance, logistics).	Proof-of-concept validation.
4. Full-Scale Integration	Expand across departments with human-in-the-loop checks.	Enterprise-wide automation.
5. Continuous Optimization	Monitor performance, refine AI models, ensure ethical compliance.	Sustained efficiency gains.

3.3. Framework Validation and Expected Outcomes

The validation of the framework and the expected results are evaluated through key operational performance indicators such as the reduction in processing time and error rates, human impact metrics such as employee satisfaction and retraining rates, and sustainability gains reflected in energy savings and waste reduction. Following this structured approach, organizations can achieve hyperautomation with end-to-end process optimization, agile decision-making with real-time adjustments driven by Artificial Intelligence, and a future-ready workforce where humans focus on innovation rather than repetitive tasks. This framework constitutes an innovative and applicable action plan for integrating RPA and AI in the context of Industry 5.0, balancing efficiency, adaptability, and human collaboration.

4. Analysis and Conclusions

The deployment of RPA and AI within the Industry 5.0 context presents both significant opportunities and complex challenges.

One of the central discussions emerging from this work relates to the observed disconnect between strategic vision and technological execution in many industrial contexts. The proposed framework bridges this gap by offering not merely a technological stack, but an implementation logic grounded in progressive, human-inclusive transformation. Each stage—from assessment to optimization—ensures alignment between executive intent and operational reality.

Cultural inertia and fear of redundancy remain critical barriers to adoption. The framework's emphasis on continuous workforce upskilling and ethical governance directly addresses these concerns. By positioning automation as an enabler of human creativity rather than its replacement, organizations can foster a culture of innovation and adaptability.

Another salient discussion point involves the interoperability of diverse RPA and AI platforms. The framework allows for technology-agnostic adoption, accommodating tools such as UiPath, Blue Prism, or open-source AI models. This flexibility enhances scalability and future-proofs the investment against technological obsolescence.

Despite its adaptive design, the framework is not without limitations. The multi-layered approach, while ensuring modularity and customization, may introduce complexity in implementation, potentially slowing initial deployment or requiring additional coordination efforts across stakeholders. For instance, the interdependence between layers—such as data infrastructure, AI integration, and human oversight—could create bottlenecks if one component underperforms. Moreover, the emphasis on ethical governance and human-centricity, though crucial, might reduce short-term efficiency gains compared to purely technology-driven automation approaches. Organizations must therefore carefully balance the framework's comprehensive structure with their operational readiness, ensuring that the pursuit of holistic integration does not inadvertently dilute scalability or ROI in the early stages.

The Industry 5.0 paradigm mandates a rethinking of ethics in automation. The inclusion of explainable AI and human oversight mechanisms in the framework addresses concerns related to bias, decision opacity, and accountability. This positions organizations to navigate emerging ethical standards and societal expectations regarding transparency and digital responsibility.

Ultimately, the framework serves as a strategic differentiator for firms operating in competitive, fast-evolving markets. While its multi-layered design may demand careful governance to mitigate implementation complexity, organizations that successfully navigate these challenges can unlock sustained competitive advantage. By harmonizing RPA and AI integration with human-centric values—rather than pursuing automation in isolation—firms position themselves to achieve resilience, customer-centricity, and innovation that are both scalable and ethically grounded.

The proposed framework is the result of a structured and critical synthesis of the literature, designed to address the multifaceted demands of industrial transformation in the era of Industry 5.0. Rather than merely presenting a conceptual abstraction, it provides an action-oriented structure, delineated in five progressive stages that reflect the essential steps required for successful integration of Robotic Process Automation (RPA) and Artificial Intelligence (AI). Each stage—ranging from strategic assessment to ethical governance and continuous optimization—was informed by patterns and challenges recurrently identified in the reviewed literature, including technology misalignment, lack of human-centered design, fragmented data ecosystems, and insufficient regulatory adaptation. In this regard, the framework is grounded in observed industrial pain points, and each of its components maps directly to an actionable domain: from identifying organizational readiness and technical maturity, to ensuring inclusive training programs, scalable technological choices, and the implementation of transparent and auditable AI systems.

While empirical deployment is not yet part of this study's scope, the framework's practical orientation derives from its alignment with recurring best practices and failure patterns documented across diverse case studies, industry reports, and academic sources. For example, the inclusion of modular layers and technology-agnostic implementation reflects lessons from industries that faced vendor lock-in or failed scalability. The emphasis on human–machine synergy and ethical oversight responds to widespread concerns around workforce resistance, algorithmic opacity, and social sustainability. In this sense, the framework does not claim to offer a prescriptive, one-size-fits-all solution; rather, it offers a configurable blueprint that organizations can adapt to their context, serving both as a roadmap and a reflective tool to anticipate integration bottlenecks and success factors.

Furthermore, its structure encourages iterative evaluation and evolution, which is critical in a technological landscape characterized by rapid change and regulatory flux. By embedding principles of transparency, collaboration, and continuous learning into its foundation, the framework aspires to promote not just automation, but responsible, resilient transformation. Thus, the claim that it constitutes a "novel, actionable blueprint" is not a logical leap, but a logical conclusion drawn from the convergence of theoretical insights, practical gaps, and design principles extracted from the literature. Still, we acknowledge that empirical validation is essential to confirm its real-world applicability, and we explicitly propose such validation as a central path for future research.

This study set out to explore how the integration of Robotic Process Automation (RPA) and Artificial Intelligence (AI) within the context of Industry 5.0 could transform industrial operations. Through the development and presentation of a structured, five-stage framework, it has delivered a robust, actionable response to the central research question:

RQ: *How can the integration of Robotic Process Automation (RPA) and Artificial Intelligence (AI) in Industry 5.0 optimize industrial processes, promoting operational efficiency, human–machine collaboration, and sustainable practices, and what are the main challenges and opportunities associated with their implementation?*

The findings confirm that when thoughtfully implemented, the convergence of RPA and AI has the potential to dramatically optimize industrial processes, enhance decision-making agility, and foster meaningful collaboration between humans and machines. Furthermore, the framework demonstrates how this integration can be accomplished in a manner that supports sustainability, ethical compliance, and long-term workforce development. It is important to clarify that this study assumes the nature of a review of the state of the art combined with the theoretical proposition of a structured framework. The main objective was to explore, based on the current and relevant literature, how the integration between Robotic Process Automation (RPA) and Artificial Intelligence (AI) in the context of Industry 5.0 can be structured to promote operational efficiency, human–machine collaboration, and sustainable practices. Thus, the answer to the research question is not based on empirical data from a practical implementation, but rather on a critical synthesis of the existing literature and a conceptual proposal that could serve as a basis for future studies. We recognize this limitation and consider that the empirical validation of the proposed model represents a fundamental step to be developed in subsequent works.

The adoption of the PICO methodology was instrumental in shaping the framework. By providing a rigorous, structured lens through which we analyze the population (industrial sectors), intervention (RPA and AI integration), comparison (varying levels of adoption), and outcomes (efficiency, sustainability, human impact), PICO enabled the construction of a framework rooted in empirical evidence and real-world applicability. It ensured that the research remained focused, transparent, and aligned with both academic and industry needs.

Limitations of this research include the lack of empirical testing within live industrial environments, which future studies should seek to address through pilot implementations and longitudinal impact assessments. Moreover, as AI technologies evolve, the framework will require periodic recalibration to remain aligned with state-of-the-art developments and regulatory landscapes.

Future research directions include the empirical validation of the framework in different industrial sectors, the exploration of sector-specific customizations, and the development of maturity models to guide organizations through various stages of intelligent automation adoption.

In conclusion, this study offers a timely, strategic contribution to both academic scholarship and industrial practice. By delivering a coherent roadmap for the integration of RPA and AI in line with Industry 5.0 values, it empowers organizations to pursue technological advancement without sacrificing human-centered design, ethics, or sustainability.

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