
| **RESEARCH ARTICLE**

Internet of Things (IoT) in Smart Factories: A Systematic Review

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| **ABSTRACT**

This systematic review investigates the integration and impact of the Internet of Things (IoT) in smart factories, an area of increasing importance in the advancement of Industry 4.0. The study synthesizes findings from numerous recent research articles, case studies, and industry reports to provide an overarching understanding of IoT applications in manufacturing environments. Key thematic areas include IoT-enabled automation, predictive maintenance, supply chain optimization, energy management, and quality control. The review highlights the transformative benefits of IoT, such as enhanced operational efficiency, reduced downtime, and improved product quality. It also discusses the challenges faced by industries in IoT adoption, including cybersecurity risks, data management issues, and the need for substantial initial investments in infrastructure. Through a comprehensive analysis, this review aims to delineate the current landscape, emerging trends, and future directions of IoT implementation in smart factories, offering insights for both practitioners and researchers in the field.

| **KEYWORDS**

IoT, Industry 4.0, Quality control, Smart factories, Smart factories.

| **ARTICLE INFORMATION**

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1. Introduction

The rapid advancement of technology in recent decades has significantly transformed various industries, with the manufacturing sector being at the forefront of these changes. Central to this industrial evolution is the integration of the Internet of Things (IoT) within smart factories, a development that signifies the convergence of the physical and digital worlds (Cheng, 2018). This transformation, commonly referred to as the fourth industrial revolution or Industry 4.0, leverages IoT to create interconnected manufacturing systems that optimize production processes, enhance operational efficiency, and improve product quality.

IoT, defined as the network of physical devices embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the internet, plays a pivotal role in smart manufacturing environments (Grabowska, 2020). By harnessing real-time data and advanced analytics, IoT enables manufacturers to make informed decisions, predict system failures, and streamline operations across various domains, from supply chain management to production line optimization.

The integration of IoT in smart factories not only promises increased agility and responsiveness but also fosters innovation in product design and manufacturing processes. It supports the development of adaptive systems capable of customized and small-batch production, aligning with the growing demand for personalized products (Kumar, 2018). Furthermore, the implementation of IoT in manufacturing settings can lead to substantial cost

savings through predictive maintenance and energy management, reinforcing the economic viability of these technologies.

Despite the promising advancements and the potential benefits of IoT in smart factories, the widespread adoption of these technologies presents several challenges. Issues related to interoperability, data security, and privacy, as well as the need for robust infrastructure and a skilled workforce, pose significant obstacles (Mourtzis, 2022). Additionally, evaluating the return on investment and measuring the impact on sustainability is critical for fostering the adoption of IoT in the industrial sector.

Given the transformative potential of IoT in smart manufacturing and the complexities associated with its adoption, a comprehensive understanding of existing research is essential (Park, 2019). This systematic review aims to consolidate current knowledge, identify emerging trends, and uncover gaps within the literature on IoT in smart factories. By analyzing recent studies and developments, this review seeks to provide valuable insights for researchers, practitioners, and policymakers interested in harnessing IoT to revolutionize manufacturing processes and outcomes (Santhosh, 2020). Through this investigation, we endeavor to elucidate the ways in which IoT is reshaping the industrial landscape, thereby informing future strategic initiatives in the realm of smart manufacturing.

2. Literature Review

The integration of the Internet of Things (IoT) into manufacturing has heralded a new era for industrial production, often termed Industry 4.0. This evolution towards smart factories is characterized by the interconnectedness of machines, advanced data analytics, and real-time decision-making processes (Tao, 2017). This literature review systematically explores current research concerning the application of IoT in smart factories, highlighting key themes, advancements, and challenges.

The theoretical underpinnings of IoT in smart factories revolve around cyber-physical systems (CPS), which integrate computational algorithms and physical processes through embedded systems. Numerous studies (e.g., Yang, 2019; Zhong, 2017) have posited that this integration facilitates real-time monitoring and control of manufacturing processes. These works emphasize the importance of interoperability, scalability, and reliability, which are fundamental for achieving the seamless integration of IoT technologies.

IoT in smart factories relies on diverse technologies such as sensor networks, connectivity protocols (e.g., MQTT, CoAP), and edge computing. Research by Wu (2022) highlights the critical role of wireless sensor networks (WSNs) in acquiring real-time data from the production floor. Meanwhile, edge computing is increasingly gaining traction (Shariatzadeh, 2016), allowing local data processing to reduce latency and bandwidth usage, which is essential for time-sensitive manufacturing applications.

Big data analytics forms a cornerstone of IoT-driven smart factories. Numerous studies (e.g., Ruiz Zúñiga, 2017; Okeme, 2021) focus on the transformation of raw data into actionable insights. Machine learning algorithms, predictive analytics, and digital twins are recurrent themes, allowing manufacturers to optimize production, predict maintenance needs, and enhance operational efficiency. The integration of artificial intelligence (AI) is also explored, offering capabilities for autonomous decision-making and self-optimization.

The practical applications of IoT in smart factories are vast, ranging from predictive maintenance to inventory management and quality control. For instance, the work by Lin (2019) showcases how IoT-enabled predictive maintenance can significantly reduce downtime and extend equipment life. Studies like those by Hozdić (2015) delve into supply chain optimization, demonstrating how real-time data and IoT systems improve logistical efficiency and responsiveness.

Despite its potential, deploying IoT in smart factories faces several challenges. Security and privacy concerns are paramount, as highlighted by Goundar (2021), due to the increased attack surface that interconnected devices present. Furthermore, issues related to data interoperability, technological standardization, and the initial cost of deployment are frequently discussed barriers (Chehri, 2019). Addressing these challenges is crucial for the widespread adoption of IoT technologies in manufacturing.

Emerging research points toward the integration of advanced technologies such as blockchain for enhanced security (Diao, 2022) and 5G connectivity for improved data transmission rates. Furthermore, the focus is shifting towards developing smart factories that are not only efficient but also sustainable, integrating IoT with green technologies (Hwang, 2017).

3. Methodology

The methodology section of this study outlines the systematic approach employed to conduct a comprehensive review of secondary data on the application of the Internet of Things (IoT) in smart factories. This section aims to elucidate the processes involved in data collection, selection, and analysis to ensure the reliability and validity of the findings. The methodology is structured under the following subheadings: Research Design, Data Sources, Data Collection, Inclusion and Exclusion Criteria, Data Analysis, and Limitations.

3.1 Research Design

This study employs a systematic review design to collate and synthesize existing research on the implementation and impact of IoT in smart factories. A systematic review methodology was chosen due to its rigorous approach to identifying, evaluating, and integrating findings from multiple studies, enabling a comprehensive understanding of the current landscape. This design facilitates the identification of research gaps, trends, and implications for practice within the domain of IoT-enabled smart manufacturing.

3.2 Data Sources

The study utilized secondary data derived from a wide array of reputable sources, including academic journals, conference proceedings, industry reports, and relevant white papers. Key databases such as IEEE Xplore, ScienceDirect, and Google Scholar were searched to ensure comprehensive coverage of the literature. Additionally, industry-specific publications and reports were incorporated to capture a holistic view of IoT applications in smart factories.

3.3 Data Collection

Data collection was conducted through a systematic literature search using specific keywords and phrases relevant to the research topic, such as "IoT in smart factories," "industrial IoT," and "smart manufacturing." Boolean operators were used to refine search queries and ensure the retrieval of pertinent studies. The search period was restricted to publications from 2010 to the present to focus on recent advancements in IoT technologies. Reference lists of selected studies were also scanned to identify additional relevant sources.

3.4 Inclusion and Exclusion Criteria

To maintain the quality and relevance of the review, explicit inclusion and exclusion criteria were established. Studies were included if they focused on IoT applications and technologies within smart factories, investigated their impact on manufacturing processes, and were published in English. Exclusion criteria encompassed studies that were not peer-reviewed, focused on non-manufacturing sectors, or were found to be outdated in the context of technological advancements.

3.5 Data Analysis

Thematic analysis was employed to analyze the collected data systematically. This involved coding and categorizing key themes and patterns related to IoT applications, benefits, challenges, and future prospects in smart factories. The analysis sought to synthesize findings across studies to generate insights into the role of IoT in enhancing

manufacturing efficiency, flexibility, and competitiveness. Further, a comparative analysis was conducted to identify differences and commonalities in IoT adoption across different industrial sectors.

3.6 Limitations

While this study offers valuable insights, certain limitations must be acknowledged. The reliance on secondary data means the study's findings are contingent on the availability and quality of existing literature. Potential publication bias may have led to an overrepresentation of positive results in the reviewed studies. Furthermore, the dynamic and rapidly evolving nature of IoT technologies could imply that newer developments may not be fully captured in the reviewed literature.

4. Findings and Discussion

4.1 Overview of IoT Integration in Smart Factories

4.1.1 Current Adoption and Trends

The integration of the Internet of Things (IoT) in smart factories has witnessed significant progress in recent years. Currently, the adoption of IoT in industrial settings has become more pronounced, with many companies transitioning from pilot projects to full-scale implementations. According to a recent report by Lee (2017), over 75% of manufacturing firms in developed regions have adopted IoT technology in some capacity, signifying a growing recognition of its potential to enhance operational efficiency and competitiveness.

Emerging trends in IoT technologies and applications in smart factories include the use of advanced sensors and edge computing to enable real-time data processing and analytics. This has led to improved predictive maintenance, reducing downtime by up to 30%, as noted by a study from Nguyen (2019). Additionally, the integration of IoT with machine learning and artificial intelligence is becoming mainstream, enabling advanced analytics for optimizing supply chain processes. Another significant trend is the increase in collaborative robotics, where IoT enables seamless interaction between humans and machines on the factory floor, as demonstrated in the scholarly work of Rong (2016).

The adoption trends are supported by the broader push for Industry 4.0, where IoT acts as a cornerstone technology. The shift towards decentralized, flexible manufacturing is evident in recent developments such as 3D printing and digital twins, which allow for virtual modeling of production processes to enhance decision-making and reduce waste, as highlighted by Shrouf (2014).

4.1.2 Key Drivers and Barriers

Several key drivers are facilitating the integration of IoT in smart factories. One primary driver is the demand for enhanced operational efficiency and reduced production costs. IoT technologies facilitate real-time monitoring and data-driven decision-making, leading to streamlined processes and improved resource management. Another driver is the need for scalability and flexibility in manufacturing operations to quickly adapt to changing market demands. IoT enables highly responsive manufacturing systems that can easily accommodate custom orders and adjustments, as discussed by Wang (2016).

Additionally, regulatory and environmental pressures are driving IoT adoption. With an increased focus on sustainability, IoT solutions allow for better energy management and waste reduction, aligning with global sustainability goals. This has been significantly encouraged by policies and incentives provided by governments worldwide, fostering a more conducive environment for IoT implementation in industries, as noted by Zemrane (2020).

Despite its advantages, the adoption of IoT in smart factories faces several barriers. One major challenge is the high upfront cost related to IoT infrastructure and technology deployment. Many factories, particularly small and medium enterprises (SMEs), struggle with the financial investments required for IoT integration. Furthermore, data security and privacy concerns hinder widespread adoption, as IoT systems often involve extensive data exchange that could be vulnerable to cyber threats, as pointed out by Chen (2017).

Another barrier is the lack of standardized protocols and interoperability issues among diverse IoT devices and platforms. The absence of universal standards complicates seamless integration, creating silos that limit the potential gains from IoT initiatives (Cheng, 2018). Skills gaps and resistance to change within organizational cultures also pose significant challenges to adoption, as workers require reskilling to manage and interact with new IoT technologies effectively.

4.2 Technological Components and Architectures

The advent of the Internet of Things (IoT) in smart factories has revolutionized industrial operations by interlinking various technological components and architectures (Grabowska, 2020). This section provides a systematic analysis of the core components, including IoT devices and sensors, network and connectivity solutions, and data management and analytics, which collectively form the backbone of smart factory ecosystems.

4.2.1 IoT Devices and Sensors

In smart factories, IoT devices and sensors are pivotal in facilitating seamless communication and automation. Commonly used IoT devices include RFID tags, temperature sensors, pressure sensors, and actuators. For instance, RFID tags play a crucial role in inventory management by providing real-time tracking of materials and products, thereby reducing human error and enhancing efficiency (Lee, 2017). Temperature and pressure sensors, on the other hand, are often utilized in monitoring equipment and environmental conditions, ensuring that industrial processes adhere to safety and quality standards.

The functionalities of these devices extend to condition monitoring and predictive maintenance. For example, vibration sensors mounted on machinery can detect anomalies and predict potential failures, thus averting costly downtime. This application of IoT devices aligns with studies by Zhong (2017), which emphasize the cost-saving potential of predictive maintenance through advanced sensor technologies.

4.2.2 Network and Connectivity Solutions

Robust network and connectivity solutions are imperative for the effective operation of IoT systems within smart factories. Technologies such as 5G and Low Power Wide Area Networks (LPWAN) are gaining prominence due to their ability to support massive IoT device connectivity and rapid data transmission (Wang, 2016). 5G, with its high-speed and low-latency capabilities, enables real-time data communication, which is crucial for applications like augmented reality in maintenance and remote machinery operation.

However, connectivity introduces challenges primarily related to data security, reliability, and latency. Interference and network congestion can lead to data transmission delays, impacting real-time decision-making processes. Furthermore, as highlighted by Shrouf (2014), there is a growing concern over cybersecurity threats posed by an increased number of connected devices, necessitating robust encryption protocols and secure authentication mechanisms.

4.2.3 Data Management and Analytics

In smart factories, the volume of data generated by IoT devices is substantial, necessitating efficient data management and analytics strategies. Data collection and storage mechanisms are often built on cloud and edge computing infrastructures, which offer scalability and flexibility (Ruiz Zúñiga, 2017). Cloud computing facilitates centralized data storage and allows for comprehensive data analysis, whereas edge computing supports localized data processing, reducing latency and bandwidth usage.

The application of data analytics and machine learning in smart factories enables optimization of operations, quality control, and enhanced decision-making. Machine learning algorithms can identify patterns in production data to optimize workflows and reduce waste. For instance, predictive analytics can forecast demand, allowing for better resource allocation and inventory management. This is corroborated by the work of Okeme (2021), which demonstrates the efficiency improvements achievable through data-driven insights.

4.3 Impact on Operational Efficiency and Productivity

The integration of Internet of Things (IoT) technologies in smart factories has demonstrated significant improvements in operational efficiency and productivity. Through real-time data collection and advanced analytics, manufacturers are able to optimize processes, enhance maintenance practices, and improve quality control and traceability (Hozdić, 2015). This section delves into how IoT impacts these aspects with examples and connections to existing literature.

4.3.1 Process Optimization

IoT technologies play a crucial role in optimizing manufacturing processes by connecting devices, machinery, and systems to facilitate seamless communication and real-time data exchange. This interconnected environment allows for enhanced process monitoring and control, leading to increased efficiency. For example, Schneider Electric's implementation of IoT solutions in their factories, as detailed by Chen (2017), resulted in a 20% increase in overall equipment efficiency. By leveraging IoT-enabled sensors and analytics, they were able to detect bottlenecks and inefficiencies in their production line, thus enabling real-time adjustments and continuous process improvements.

Additionally, IoT facilitates the utilization of digital twins—virtual replicas of physical systems—to simulate and optimize production processes. A study by Goundar (2021) highlighted how digital twins, powered by IoT data, allowed a major automotive manufacturer to reduce production cycle time by identifying optimal machine settings and workflow sequences, consequently enhancing product output.

The findings align with previous research, such as that by Mourtzis (2022), which emphasized the transformative potential of IoT in creating more responsive and efficient production systems, thereby reducing waste and costs.

4.3.2 Predictive Maintenance and Asset Management

The application of IoT in predictive maintenance has revolutionized traditional maintenance practices in manufacturing settings. IoT sensors continuously monitor equipment health, providing data-driven insights into machine performance and potential failures (Rong, 2016). This approach allows for predictive maintenance, which foresees equipment issues before they manifest into significant problems, reducing downtime and maintenance costs.

A case study involving a leading aerospace manufacturer, as reported by Shariatzadeh (2016), demonstrated how IoT-based predictive maintenance systems reduced unexpected equipment failures by 35%, resulting in significant savings in operational costs. By employing advanced analytics to evaluate parameters such as vibration, temperature, and pressure, manufacturers can schedule timely maintenance activities and extend the lifespan of their assets.

The benefits of these techniques resonate with the findings of Yang (2019), who concluded that IoT-driven predictive maintenance not only enhances asset availability but also optimizes spare parts inventory, reducing maintenance-related operational expenditures.

4.3.3 Quality Control and Traceability

IoT contributes significantly to improving quality control by enabling real-time monitoring and immediate responses to deviations in product quality. IoT systems collect and analyze data across various stages of the production process, ensuring that quality standards are consistently met. A study by Santhosh (2020) illustrated how an industrial IoT setup helped a consumer electronics manufacturer decrease defect rates by providing instant alerts for irregularities during production, thus allowing corrective actions to be taken promptly.

Traceability in supply chain management is another area substantially impacted by IoT. By tagging products with IoT-enabled sensors and RFID technology, companies can track materials and finished goods through every step of the supply chain. This capability not only enhances transparency but also improves the ability to trace the origin of

quality issues. For instance, IBM's collaboration with a dairy firm, as described by Park (2019), used IoT for real-time tracking of milk from farm to store, ensuring end-to-end quality control and supply chain visibility.

The advancements in IoT-facilitated quality control and traceability align with the conclusions of previous studies, such as that of Lin (2019), which pointed out the growing importance of IoT in ensuring product quality and mitigating risks across complex supply chains.

4.4 Security, Privacy, and Trust Issues

In the context of smart factories, the integration of Internet of Things (IoT) technologies has brought a new dimension to industrial operations, optimizing processes and increasing efficiency. However, this advancement also introduces significant security, privacy, and trust issues (Hwang, 2017). This section discusses the various challenges and concerns related to IoT implementations in smart factories and explores strategies to address them.

4.4.1 IoT Security Challenges

The deployment of IoT systems in smart factories presents unique security challenges. One primary issue is the increased attack surface due to the multitude of interconnected devices. Each device can serve as a potential entry point for cyber threats, as demonstrated by the Mirai botnet attack, which exploited vulnerable IoT devices to launch widespread distributed denial-of-service (DDoS) attacks (Kumar, 2018). Such vulnerabilities arise from several factors, including poor device-level security protocols, lack of standardization across IoT devices, and limited computational resources to support advanced security measures.

Common vulnerabilities in IoT systems include weak authentication mechanisms, insecure data transmission, and inadequate device management. For instance, many IoT devices use default or hard-coded passwords, making them susceptible to unauthorized access (Nguyen, 2019). Potential threats range from data breaches and espionage to sabotage of critical manufacturing operations. A study by Tao (2017) highlights the risk of advanced persistent threats (APTs) targeting IoT devices to disrupt production processes.

4.4.2 Privacy Concerns and Mitigation Strategies

Data privacy is a paramount concern in IoT-enabled smart factories, primarily due to the vast amounts of sensitive information collected and processed. IoT devices continually gather data related to production processes, machinery performance, and sometimes even employee movements. This raises significant privacy issues, as unauthorized data access or misuse could lead to intellectual property theft or violate employee privacy rights (Wu, 2022).

To mitigate these privacy risks, several strategies and technologies have been proposed. Data anonymization and pseudonymization techniques can reduce risks by ensuring that personally identifiable information is not easily traceable (Zemrane, 2020). Moreover, implementing robust access control mechanisms, such as role-based access controls (RBAC), can help limit data access to authorized personnel only. Blockchain technology has also been suggested as a means to enhance data integrity and privacy, providing a transparent and tamper-proof record of data transactions (Chehri, 2019).

4.4.3 Building Trust in IoT Systems

Trust is a critical factor in the widespread adoption and success of IoT systems within smart factories. Building trust involves ensuring transparency, security, and accountability throughout the IoT ecosystem. One method to enhance trust is through the implementation of transparent data handling practices, where stakeholders have clear insights into how data is collected, used, and shared (Diao, 2022).

Accountability can be facilitated through regular security audits and compliance with industry standards and regulations such as the General Data Protection Regulation (GDPR) for data privacy (Ruiz Zúñiga, 2017). Additionally, adopting secure-by-design principles, where security is integrated from the outset of device development rather than as an afterthought, can help create more trustworthy systems (Okeme, 2021).

Furthermore, fostering collaborations between manufacturers, technology providers, and regulatory bodies can help establish a unified front against security and privacy challenges, building greater trust in IoT technologies over time. These collaborative efforts have shown promise in previous studies that underscore the importance of multi-stakeholder engagement in enhancing IoT security and trust (Lin, 2019).

4.5 Future Directions and Research Opportunities

4.5.1 Emerging Technologies and Innovations

As the Internet of Things (IoT) continues to evolve, several emerging technologies promise to significantly enhance the capabilities of smart factories. Edge computing is one such innovation likely to transform how data is processed within industrial environments. By enabling data analysis closer to the source, edge computing reduces latency and bandwidth usage, resulting in faster decision-making and real-time insights. A study by Hwang (2017) highlights how edge computing can streamline operations in manufacturing settings, potentially leading to cost savings and efficiency improvements.

Another promising area is the integration of Artificial Intelligence (AI) and Machine Learning (ML) algorithms with IoT systems. These technologies support predictive maintenance, anomaly detection, and quality control through continuous learning and adaptation. For instance, Chehri (2019) demonstrated the application of AI in predictive maintenance, showing how equipment downtime in factories could be minimized by predicting failures before they occur.

Blockchain technology, with its decentralized and secure framework, also presents an opportunity for enhancing supply chain transparency and traceability in smart factories. Projects like those outlined by Diao (2022) indicate potential benefits in ensuring product authenticity and reducing counterfeiting, which is particularly important in industries like pharmaceuticals and high-tech manufacturing.

Innovative applications in the research and development stages also present potential. For example, the use of digital twins—virtual replicas of physical assets—can simulate factory operations to optimize design and processes without physical trials. Research by Rong (2016) suggests that digital twins can significantly enhance prototyping and predictive analytics, making factories more adaptive and responsive.

4.5.2 Research Gaps and Open Challenges

Despite these promising developments, several gaps remain in the current research landscape. One significant area needing more exploration is cybersecurity within IoT-enabled smart factories. As IoT devices proliferate, they can become susceptible to cyberattacks, posing risks to operational continuity and data integrity. Studies such as those by Kumar (2018) emphasize the need for more robust and adaptive security frameworks that can protect diverse IoT ecosystems in industrial settings.

Interoperability between different IoT systems and legacy infrastructure in factories also presents a challenge. The piecemeal adoption of IoT technologies can result in fragmented systems that do not communicate effectively. Research is needed to develop standard protocols and interfaces that ensure seamless integration across various technologies and platforms, as noted by Shrouf (2014).

Additionally, there is a knowledge gap regarding the socio-economic impacts of IoT adoption in manufacturing. While technological advancements are well-documented, less attention is given to the implications for the workforce, including skill requirements, job displacement, and training needs. Future research could benefit from exploring these dimensions to provide a more comprehensive understanding of IoT's impact on manufacturing employment and skill development.

Finally, sustainable practices in IoT implementation present another research opportunity. The environmental implications of deploying large numbers of IoT devices, particularly concerning energy consumption and electronic waste, are still understudied. Research focusing on eco-friendly IoT solutions and lifecycle management could

contribute to more sustainable smart factory operations, aligning with global sustainability goals, as discussed by Wu (2022).

Addressing these gaps through focused research initiatives will not only advance academic knowledge but also further the practical applications of IoT in smart factories, fostering more resilient, efficient, and sustainable manufacturing landscapes (Zhong, 2017).

5. Conclusion of Findings

The systematic review of the Internet of Things (IoT) in smart factories underscores the transformative potential of IoT technologies in enhancing manufacturing processes and operational efficiencies. Through the extensive analysis of current literature, it is evident that IoT-enabled smart factories are paving the way for unprecedented levels of automation, data-driven decision-making, and interconnected systems. This transformation is not only optimizing production workflows but also leading to significant cost reductions and improved product quality.

Key findings from this review highlight the importance of IoT in facilitating real-time monitoring, predictive maintenance, and supply chain integration. The deployment of IoT devices and sensors enables manufacturers to gain insights into equipment performance, anticipate failures, and reduce downtime, thus ensuring a more resilient and responsive manufacturing environment. Furthermore, the integration of IoT with emerging technologies such as artificial intelligence and big data analytics is accelerating innovation and fostering adaptive manufacturing systems.

Despite the evident benefits, the study also identifies several challenges that need to be addressed to fully realize the potential of IoT in smart factories. These include concerns related to data security, interoperability of IoT devices, and the need for robust network infrastructure. Additionally, the workforce skills gap poses a significant challenge, necessitating focused efforts on training and upskilling to enable seamless adoption of these technologies.

In conclusion, while IoT in smart factories is still in an evolutionary phase, its impact on the manufacturing sector is profound. For stakeholders, including manufacturers, policymakers, and technology developers, strategic collaboration and continuous investment in IoT innovations are crucial. As the technological landscape evolves, it is imperative to address the existing challenges and explore new frontiers in IoT applications to ensure sustainable growth and competitive advantage in the era of Industry 4.0. Future research should focus on developing standardized frameworks and exploring scalable IoT solutions that can be tailored to diverse manufacturing contexts, thereby driving broader adoption and industrial advancement.

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