Leveraging Internet of Things (IoT) and Artificial intelligence (AI) to Optimize Supply Chain Systems

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Received Nov 04, 2024, **Revised:** Dec 20, 2024, **Accepted:** Dec 25, 2024, **Published Online:** Dec 28, 2024
Reviewers: Anonymous Peer Review
Citation: Raman, R., Selvaraj, M. (2024). Leveraging Internet of Things (IoT) and Artificial intelligence (Al) to Optimize Supply Chain Systems. *International Journal of Supply Chain Management*, *13*(6), 1-9, https://doi.org/10.59160/ijscm.v13i6.6272

Abstract- Some emerging technologies transforming supply chain management (SCM) include the Internet of Things (IoT) and Artificial Intelligence (AI). Their abilities provide the tools companies need to evolve and meet the changing needs and business conditions, ensuring they remain afloat. The challenge, however, is understanding how companies can incorporate the technologies into their systems. There are also concerns over the low adoption rates among small and medium enterprises (SMEs), and the paper looks into the issue to assess the barriers and solutions. The other goal is to determine strategies companies use to optimize AI and IoT to ensure proper supply chain management. This paper contributes to supply chain management by providing a structured framework for integrating AI and IoT technologies to enhance operational efficiency, real-time decision-making, and supply chain visibility. It addresses barriers faced by SMEs, such as financial constraints and lack of skilled personnel, offering strategies like innovative leadership and collaboration through ecosystems to overcome these challenges. Additionally, the research highlights how AI and IoT strengthen supply chain resilience, optimize inventory, and ensure seamless operations, especially in adapting to post-pandemic vulnerabilities. The literature review was done on recent scholarly research papers and case studies. The findings showed that SMEs can overcome challenges such as limited funds and human resource constraints by collaborating with others and getting innovative leaders to lead the supply chains. Supply Chain Systems (SCS) that adopt AI and IoT can leverage them to ensure optimized inventory management, tracking and quality control, predictive analysis abilities, and continuous monitoring, which provide constant system improvement.

Keywords*: Supply Chain Management, Artificial Intelligence (AI), Internet of Things (IoT), Operational Efficiency, Small and Medium Enterprises (SMEs), Data Analytics, Supply Chain Visibility, Technology Integration, Real-time Decision Making, Predictive Analysis*

1. Introduction

The supply chain is the backbone of the global commerce industry, given its role in facilitating the supply of goods and services across all sectors. Supply chain systems (SCS) help to ensure the efficient movement of goods and services within the complex, ever-expanding global market (Butt, 2021). Given the scope and the impact of the supply chain system, it is vital to find innovative ways to optimize efficiencies and improve its overall performance. After the pandemic, various vulnerabilities were exposed regarding the supply chain systems. Some of them included the overreliance on offshore manufacturing services. United States (US) companies relied heavily on offshore manufacturing within other outside nations such as China. The Covid-19 lockdown restrictions affected the supply chain due to the limited movement of goods and services. Such disruptions led to deliberations on how supply chain systems can mitigate such risks. The other vulnerability was the lack of diversification when relying on single countries or outsourcing. For other companies, it was the use of lean inventory management systems proved which proved futile due to the insufficient stockpiles that did not absorb the shock created by the pandemic (Butt, 2021).

Technology, through AI and IoT, is a supply chain management tool that helps develop resilience and overcome the challenges posed by the pandemic. After the pandemic, the global supply chain also changed significantly as new emerging technologies became essential for supply chain companies to remain afloat and overcome the changing market conditions. Moreover, consumer preferences also changed due to the emphasis on sustainable goods and services. An example is the growing concern for supply chain visibility as part of quality assurance for conscious consumers (Kraft et al., 2019). Such changes in the supply chain systems, global market, and consumer preferences posed a challenge for the supply chain systems of corporations and the Small and Medium Enterprises (SMEs). Most stakeholders and companies realized the importance of visibility across the supply chain. Most companies were previously operating under the silo system, which entailed limited coordination and communication at different stages of the supply chain had to change. Using outdated systems led to delays, lack of communication, and poor planning due to the lack of coordination among the stakeholders (Abdelwahab et al., 2024). Thus, the demand for visibility across the supply chain increased, and technology-enhanced visibility. IoT and AI improve visibility by creating end-to-end visibility, and access to real-time data helps in analytics and forecasting. The functions are critical in identifying and fixing anomalies within the supply chain system (Akbari & Do, 2021). The companies can thus make informed decisions and respond to any issues arising on time. Most importantly, the companies obtain the tools that allow them to develop resilience and compete with others instead of becoming obsolete.

IoT refers to the network of interconnected sponsors and devices that collect data, transmit, analyze, and avail them in real time to affect decision-making (Akbari & Do, 2021). The IoT technology gets embedded in the different nodes of the supply chain, including the different processes and stages, such as manufacturing, distribution, and transportation. It, therefore, ensures continuous monitoring of goods along the supply chain line, making it easy for the supply chain manager to track, monitor, and make informed decisions. Artificial intelligence (AI), on the other hand, is a supply chain system that uses machine learning and cognitive computing to process large datasets to identify patterns and help predict future trends. Its use within the supply chain helps make decisions to impact the supply chain performance. For example, in inventory management, AI can help forecast demand based on historical data, which helps reduce the overstocking or understocking challenge (Abdelwahab et al., 2024). Doing that promotes efficient use of resources, making it possible to reduce costs and optimize operations, strengthening the performance of the supply chain network. The real-time access to data created by the two technologies improves supply chain optimization. While the IoT collects data from different nodes, AI analyses and processes them, providing the management with sustainable insights to take proactive action to mitigate risk and ensure the systems operate optimally. Integrating IoT and AI allows the supply chain system to develop functionalities such as data input, big data, machine learning, and IoT devices, which help in analytics as the system can learn and improve the efficiency of supply chain operations. The processes are cyclic as they help review the supply chain system and update to improve operations continually.

2. Research Gap and Questions

While AI and IoT are widely adopted across the supply chain systems, gaps exist regarding optimizing the supply chain processes, the technology application in SMEs, and integrating the technologies within the supply chain systems. There is little evidence supporting the technologies' role in promoting operational efficiency. Data security, interoperability, and costs are still challenging for most companies, such as SMEs, limiting the effective use of the technologies (De Vass et al., 2021). Little research is available on how small and medium enterprises adopt and leverage the technologies to ensure supply chain visibility and efficiency (Hansen & Bøgh, 2020). SMEs have less than 250 employees and an annual turnover below 50 million euros. Their size and turnover rates make it hard for them to adopt AI and IoT compared to giant corporations with colossal supply chain systems (Akbari & Do, 2021). There is, thus, a need to gather data regarding the adoption of IoT and AI among SMEs to provide a holistic view of the situation. The other research gap concerns how the companies collect and process the data and use it to optimize the supply chain system. The research seeks to provide data to help SMEs overcome the challenges of adopting IoT and AI, among other technologies. It will also show how companies leverage AI and IoT to ensure improved visibility and operational efficiency. The data will assist other companies to understand how to adopt the technology and optimize it to ensure resilience and success in the business.

Research Objective 1. To explore the integration of AI and IoT technologies into supply chain systems for

enhancing operational efficiency and facilitating real-time decision-making.

Research Objective 2. To identify the primary barriers to AI and IoT implementation within small to medium-sized enterprises and propose strategies to overcome these challenges.

Research Objective 3. To examine the role of AI and IoT in enhancing supply chain visibility and to identify strategies for optimizing these technologies within supply chain networks.

3. Methodology

The method used to gather the evidence is a literature review. It is a process that helps to critically search and analyze data from published sources regarding an issue (Peters et al., 2020). Gathering data and answering the research gap identified within the problem statement is crucial. Some of the sources included within the study include case studies, company reports, and scholarly articles. The first step in the process was to determine the research questions and outline them to understand the scope of the research. The second step was deriving key terms and search terms from the research question to assist in finding suitable sources from reputable databases. Some of the identified keywords include "IoT in supply chain management," "AI for real-time decision making," "AI in supply chain visibility," "AI and IoT integration," and "Operational efficiency in supply chain networks," among other terms. The terms helped when searching for relevant articles from the different databases. The databases searched for in the literature review include JSTOR, Scopus, Google Scholar, and Supply Chain Management Review.

The initial search had a broad array of sources, and applying filters helped narrow the search to only the relevant sources. One of the criteria used in filtering is the publication date. Only recent studies were included in the review to ensure the delivery of current evidence regarding the issue. The other criterion was the quality of the papers. The review team only included sources from reputable and published sources. Peer-reviewed sources were prioritized to ensure that only valid and credible sources were used (Peters et al., 2020). The next step was to review the remaining articles based on their content, given that they met the first criteria. Content reviewers reviewed the article first by reading the abstract and removing irrelevant sources, and then, a second time, by reviewing the entire paper to ascertain that they benefitted the study. The next step was data extraction, which allowed the researchers to extract the relevant information and store it in themes. The strategy helped find practical applications of the technologies and provided insights into how companies integrated the technology into their supply chain.

4. Results and Discussion

4.1 Considerations for Integrating AI and IoT technologies into Supply chain systems

4.1.1 Six-Part Model of Integration

Integrating AI and IoT technologies into the supply chain management system requires various considerations. The process determines the efficacy of the technologies in promoting efficiency and streamlining operations. There is no specific technology integration model; different companies use varying methods. A study done within smart factories revealed a six-stage process for integrating AI and IoT within a company. Figure 1 shows that the stages include perception, reservation, decision, operation, interpretation, and adjustment (Kalla & Smith, 2024). The initial stage, perception, entails the proposition to the companies to use AI and IoT. The initial stage is essential because it helps employees understand the need for change and complications. It thus reduces the resistance that may arise later and increases the chances of success. Reservation and decision stages are the next ones, which help to contemplate the concept collectively while the organization addresses any concerns among the employees. Most importantly, the contemplation helps analyze the risk of acquiring new technology and how to mitigate it (Paiola & Gebauer, 2020). For example, employees may fear for their jobs or need more skills to work with the latest technologies. Such concerns are vital in allowing management to address them and reassure the stakeholders of their job safety. Operation is the other step that will enable companies to implement new technologies and create the capacity of their staff to operate through activities such as training and education. Reinforcement learning helps employees become acquainted with and use the latest systems. Workers' safety is essential, and training them on the same is crucial in reducing the risks associated with using technology, such as data breaches and bias within the algorithms.

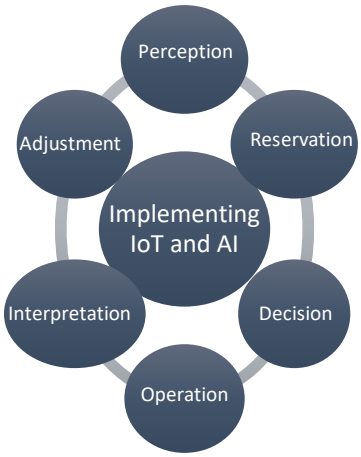

Figure 1: The six-process model for implementing IoT & AI

4.1.2 Understanding Business Needs

A study done to develop an intelligent supply chain management system suggested the importance of understanding business needs. The initial strategy was identifying the need for the technology and outlining what the company needs. This strategy is vital because companies must adopt technologies compatible with existing systems and promote outcomes (Oh, 2019). In supply chain management, various stakeholders, including the manufacturers, the customers, and the manufacturers, need to be part of ascertaining the need for technological innovations. The input from all stakeholders helps adopt technologies that improve standardization across the supply chain network. Adopting IoT calls for considering three processes, including the perception layer, network, and application, as shown in Figure 2 (Taj et al., 2023). In the perception layer, the process requires determining the architecture of the IoT system. The Bottom-up approach is critical, given that it helps determine the best architecture system to hold the system in place. The chosen architecture should help acquire data, erect the physical parameters, and implement systems for which innovative equipment will fit. The other step is determining the network layer. The network layer helps to communicate and transmit to other devices, applications, and servers to ensure interoperability and communication across the supply chain network (Paiola & Gebauer, 2020). The application layer comes last to offer the application-specific services that help the end users across the supply chain system. A solid architecture and network guarantee the effectiveness of the application layer in facilitating business processes and utilizing real-time data to inform business operations.

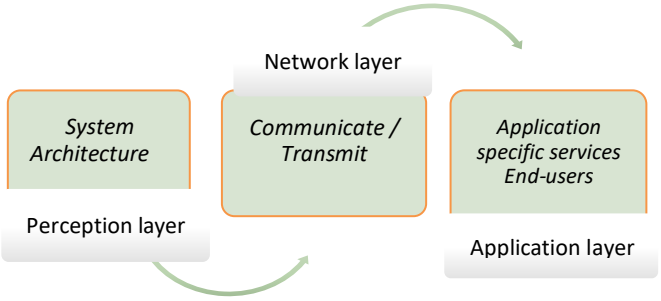

Figure 2: IOT Implementation process

4.2 Primary Barriers Affecting AI And Iot Implementation Within Small to Medium-Sized Enterprises

4.2.1 Human Resources, Limited Finances and Work Circumstances

Despite the apparent benefits of the new technologies in streamlining supply chain operations, most small and medium enterprises (SMEs) still fail to adopt the technologies. One of the primary reasons is human resources, limited finances and work circumstances. According to Horváth and Szabó (2019), SMEs' lack of skilled personnel prevents them from adopting IoT and AI. Operating such technologies takes time and skill; most SMEs lack such people. Moreover, most businesses view it as an additional cost they are unwilling to invest. Most SMEs do not have the proper infrastructure to adopt the technologies, which makes it costly for them to invest. The other reason closely related to the human resource is the cost of erecting the infrastructure for AI and IoT. Most SMEs do not have the financial capabilities to adopt the technology and thus use traditional supply chain management methods. It costs financial resources to train the workforce, pay the experts, find new technologies, and implement them. Maintaining the technologies is also challenging and may be expensive for most SMEs. Therefore, most choose not to adopt AI and IoT due to lacking resources and funds. The other workforce factor is the resistance from the different stakeholders along the supply chain, making it hard for the willing partners to adopt such technologies (Horváth & Szabó, 2019). It is hard for each stakeholder to adopt the technologies individually, which could cause incompatibility issues across the supply chain, making it hard to operate within the network (Mittal et al., 2018). Therefore, the willing parties must wait for the others to upgrade and adopt new technologies. The cultural resistance to new technologies at the point of emergence makes it hard for SMEs to utilize and

leverage technology to streamline their operations. The catch-up effect is common among SMEs as they adopt technologies once they have become mainstream, denying them a competitive advantage.

4.2.2 The evolving nature of AI and IoT and the Associated Uncertainties

The other issue is the mystery of AI and IoT technologies, which are relatively new and constantly evolving. Such matters present standardization issues for SMEs as there is concrete and specific information to allow them to make a significant investment. Large companies have the benefit of being able to afford to adopt new and emerging technologies given their revenues and allowed risk level. For SMEs, it is hard to navigate the complex and unstable landscape of AI and IoT (Horváth & Szabó, 2019). The risk of adopting such technologies outweighs the perceived benefits. Technologies are also evolving daily, and the risk of the systems becoming obsolete is high and requires constant maintenance and updating. The standardization process adds another barrier, requiring new systems to ensure compatibility. Most SMEs' supply chain systems are incompatible with the others, making it hard to standardize the acquired technology across the supply chain network (Rocha & Kishimoto, 2022). The complexity of integrating and standardizing the system presents a barrier for SMEs to adopt new supply chain technologies.

4.2.3 Cybersecurity and Data Ownership Issues

Cybersecurity and data ownership issues threaten the adoption of IoT and AI among small and medium enterprises. SMEs' limited resources make it hard to maintain the required robust security systems (Mittal et al., 2018). Adopting AI and IoT presents additional security issues for businesses. Most SMEs choose to use traditional methods they know historically to be safe rather than invest in expensive and emerging technologies that are risky. Adopting these technologies calls for sophisticated operations across the supply chain network, and most stakeholders are still waiting to step up. Additional processes require data collection, storage, transmission, and constant monitoring and evaluation of the systems. That calls for additional resources and personnel, which most SMEs are unprepared to commit to due to the tight budgets. The stakeholders who resist technological changes find it hard to incur such costs, making it impossible for the willing parties. The lack of support from the stakeholders makes it hard to adopt the technologies as most SMEs lack the organizational competence and capacity to ensure data security, leading to operational fragility issues.

4.2.4 Poor coordination

According to Mittal et al. (2018), the challenges of coordinating across the organizational units present another barrier to technology adoption in small and medium businesses. SMEs operate in distinct and uncoordinated fragments, making it hard to adopt a new system that requires proper systems and coordination activities. The decentralized nature of the SMEs and the informal nature of operations makes adopting AI and IoT impossible as it needs more accountability and structure that can extract the benefits of AI and IoT. The other characteristic of small businesses is the need for more staffing structures (Rocha & Kishimoto, 2022). Most of the time, employees have many roles, and there is no accountability, making it hard to integrate IoT, which requires specialized roles and formal systems. The fragmented supply chain network discourages inter-departmental and system collaboration and communication for IoT and AI (Oh, 2019). Implementing the technologies requires practical planning skills, which most SMEs need to gain. Long-term strategic planning is required in order to ensure the technologies work effectively and simplify the supply chain management process. The short-sighted nature of SMEs does not justify the adoption of AI and IoT, as the perceived benefits outweigh the actual risk it takes to adopt the technologies. However, big corporations with long-term strategic planning and clarity find the risk of adopting AI less than the benefits they derive. Strategic planning allows them to foresee the need for technologies and how to leverage them for success.

4.3 Strategies to Overcome the Barriers

4.3.1 The importance of innovative leadership

One of the strategies to overcome some of the limitations affecting the adoption of IoT and AI within small and medium enterprises is to develop a strong leadership team. Within the supply chain, some leaders manage and make decisions that affect daily functions across the supply chain network. The advantage of SMEs is that they have a centralized structure with the CEO, who engages in the day-to-day activities. Studies show that the CEO's personality, demographic characteristics, and extraversion affect IT usage within the organizations (Horváth & Szabó,

2019). It involves the quality of the management team and, thus, the attitude towards adopting emerging technologies. Most small businesses that adopt IT and other technologies have leaders with a positive attitude toward technology. The influence of the leaders spreads across the supply chain, which can help reduce resistance to change among the stakeholders. It also ensures collaboration and coordination across the supply chain as a visionary leader with direction supports the stakeholders. Leadership support and commitment towards innovation and efficiency impact the adoption rates for most SMEs (Alshareef & Tunio, 2022). Such leaders have the correct information and foresight for the business, which allows others to understand the technologies, their impacts, and the potential benefits they have on the businesses. Thus, leadership is essential to increase AI and IoT adoption among SMEs.

4.3.2 Collaboration through the Innovative Ecosystem Model

Another approach to eradicating the barriers preventing the integration of IoT and AI in small and medium enterprises is to collaborate with large enterprises, which can help them leverage resources and acquire AI and IoT technologies that can help them streamline operations. Different models, including the innovation ecosystem (IE) model shown in Figure 3, contain a process for attracting partners with the same vision to acquire IT technologies. The model has recently gained traction as technology has become widespread and vital in businesses. It refers to the arrangements in industry chains creating innovation clusters. It calls for different actors within the supply chain to synchronize their activities to promote innovation and improve their product or service offerings. Gu et al. (2021) recommend cooperating with external actors with complementary innovation resources. The strategy ensures mutual benefits for both stakeholders. The approach creates a supply chain management ecosystem that leverages resources from different SMEs. There is a need for the stakeholders to develop clear goals and develop non-contractual governance systems to help manage the eco-system.

Figure 3: Innovative Eco-system development process

One of the reasons why the strategy is effective is that it helps create risk management and resilience. One of the primary reasons SMEs do not adopt AI and IoT is the lack of funds and resources to adopt the technologies. The IE model allows SMEs to work together and adopt technologies that help them remain resilient using the best technological tools. It also helps in risk management as the initial capital required to erect and maintain the systems comes from the various stakeholders throughout the supply chain. Thus, a spread of risk among the members can ensure that when the technology fails, the businesses remain afloat, creating resilience and allowing the companies to take risks and try new technologies. The increased visibility means that the SMEs have better operations and reduced costs due to the forecasting and risk mitigation benefits they get from IoT and AI.

5. The role of AI and IoT in enhancing Supply Chain Visibility

5.1 Data and predictive analysis

Information processing theory hypothesizes that efficient data processing within supply chains using technologies such as AI and IoT enhances the flow of information, enhancing the quality of decision-making within the supply chain network. The Internet of Things refers to the interconnected network of devices that share data in real-time. This technology is vital in collecting data across the supply chain network

(Seyedan & Mafakheri, 2020). The connectivity across the supply chain facilitates seamless communication and creates centralized systems. The connectivity infrastructure is the baseline for data processing and information impacting decision-making. The increased visibility is due to data availability through the interconnected systems held together by the IoT. AI plays a vital role in data analytics and processing. The process transforms the raw data from the sensors into actionable insights. Different methods of processing and analyzing data include cloud computing and data analytics platforms. By analyzing trends, businesses can enhance predictive abilities and optimize resources across the supply chain to meet consumer needs. They can anticipate changes and prepare for them, which impact their operations and strategies used in stocking inventory management and distribution. The approach thus helps in proper inventory management, forecasting business needs, and making data-driven decisions that impact business outcomes.

5.2 Real-Time Tracking, Quality Control, and Visibility

IoT works differently to enhance efficiency and effectiveness in different supply chain stages. One of the ways to do this is through tracking and monitoring processes. The IoT devices help to improve real-time monitoring and tracking of goods and services across the different parties within the supply chain. The strategy ensures end-to-end visibility, which is critical in allowing companies to be aware of the movement of goods. For example, the supply chain manager can mitigate risks before they become problematic due to the visibility created. Companies use IoT to track goods, monitor shipment locations, ensure timely delivery, and trace the goods and services for quality control. Regarding the food industry, IoT helps to track the goods and ensure transparency, which most consumers are vigilant about today. Conscious consumers have raised concerns over the integrity of the production and manufacturing of particular goods (Kraft et al., 2019). Tracking the process helps to ensure quality control. It also convinces the consumers that the goods and products are organic, giving them the supply chain movement from the producer to the distributor. The data makes it easy to enforce measures to guarantee that the products and services remain within optimal conditions, minimizing losses for the business. Such a strategy ensures cost-effective supply chain operations as businesses optimize revenues and reduce losses due to the ability to mitigate risks on time.

5.3 Continuous Monitoring and Improvement

The other impact concerns the technologies' predictive maintenance abilities. IoT devices and AI offer supply chain managers tools to collect data regarding equipment performance, helping track its health. In the food industry, the technologies help to track the refrigeration units, trucks, and conveyor belts, which helps ensure that the equipment is operating optimally. As the companies collect data, they, through AI, develop predictive models in maintenance algorithms to forecast, for example, equipment failure (De Vass et al., 2021). Such projections pave the way for risk mitigation strategies as supply chain managers can plan to acquire new equipment and systems to ensure businesses remain operational and sustainable. Visibility thus yields supply chain reliance, which keeps the company afloat and maintains its competitive advantage within the industry as it can compete against others.

5.4 Inventory Optimization

Another way that AI and IoT improve supply chain visibility and efficiency is through their impact on inventory management through automation. AI allows for developing an automated inventory management system, vital in providing insights into controlling stocks and managing risk based on inventory status. IoT helps in stocking purposes through weight sensors, which detect inventory fluctuations, ensuring suppliers can replenish the stock when needed. Also, the IoT through the RFID tags helps improve warehousing efficiency through inventory tracking. It reduces the downtime and inconveniences in the old system, where there was a lack of visibility. The system prevents stockouts and excess inventory through the developed threshold, optimizes resources, and promptly delivers goods and services to consumers. The benefit of the intervention in inventory management is that it also reduces errors created through the traditional manual data entry system. There is reduced risk for data reliability issues experienced in the past due to automation and real-time tracking. It facilitates fat turnaround times and lower operational costs that promote productivity and the overall performance of the supply chain system.

6. Conclusion

IoT and AI are emerging technologies revolutionizing the supply chain management industry. Today, more than ever, they have become essential tools in each business organization, given the benefits they provide

to companies. They offer a competitive advantage over others, allowing companies to remain resilient and meet the changing demands of consumers and global markets. The literature review revealed how SCM can incorporate new technologies into the system. The discussed interventions include using the six-step model that offers a framework companies can adopt to ensure they prepare the organization for change and erect the proper infrastructure to support the IT systems. The second approach was determining business needs using the three-layered model of assessing the systems, network, and application. Some identified barriers SMEs face that prevents them from adopting IT technologies include limited finances, human resources, the evolving nature of AI, poor coordination, cyber security and data security issues. The inquiry results indicate that despite the barriers and challenges SMEs face in adopting new technologies, there are ways that SMEs can adopt emerging tools. Some recommended strategies include collaborating with others and ensuring excellent leadership that allows for innovation. After adopting the IoT and AI technologies, supply chain networks can optimize them using big data and analytics, allowing for a productive ability to foresee trends and business needs. Companies can optimize inventory through predictive analysis and automation features, ensuring efficient allocation and use of resources. The technologies allow tracking and real-time visibility, ensuring proper quality control and business risk management strategies. Increased visibility and data analytics make it easy to monitor the systems and ensure continuous improvement.

We recommend companies should adopt a structured six-stage process for integrating AI and IoT technologies into supply chain systems, focusing on stages such as perception, decision-making, operation, and adjustment to ensure seamless adoption and continuous improvement. Small and Medium Enterprises (SMEs) should prioritize fostering innovative leadership to drive the adoption of these technologies, as visionary leaders can reduce resistance to change and encourage collaboration across supply chain networks. Additionally, SMEs are encouraged to collaborate with larger enterprises through innovative ecosystem models, allowing for the pooling of resources, sharing of risks, and mutual benefits in adopting and utilizing advanced technologies. To further enhance supply chain operations, networks should implement IoT for real-time tracking and AI for predictive analytics to optimize inventory management, improve visibility, and ensure effective risk mitigation. Finally, companies should address barriers like limited finances, human resource constraints, and cybersecurity risks by adopting scalable solutions, training employees, and implementing robust data security measures to enable effective technology adoption and integration.

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