Financial Risk and Management Reviews
2025 Vol. 11, No. 1, pp. 72-102
ISSN(e): 2411-6408
ISSN(p): 2412-3404
DOI: 10.18488/89.v11i1.4143

Revolutionizing supply chains: The role of emerging technologies in digital transformation

Naimul Islam[1]
Tipon Tanchangya[2]
Kamron Naher[3+]
Ummah Tafsirun[4]
Md Rakib Mia[5]
Shoaibur Rahman Sarker[6]
Fahad Rashid[7]

[1]*Department of Accounting, Finance and Economics, University of Greenwich, SE10 9LS, London, UK.*
Email: naimmgtdu75@gmail.com
[2]*Department of Finance, University of Chittagong, Chittagong 4331, Bangladesh.*
Email: tipon.tcg.edu@gmail.com
[3]*Department of Business Administration, Presidency University, Dhaka-1212, Bangladesh.*
Email: naherk@pu.edu.bd
[4]*Department of Business Administration, Sonargaon University, Dhaka, 1215, Bangladesh.*
Email: ummah.tafsirun@gmail.com
[5]*Department of Business Administration, Ahsanullah University of Science and Technology, Dhaka 1208, Bangladesh.*
Email: mdrakibmia087@gmail.com
[6]*School of Business and Law, Northumbria University, 110-114 Middlesex Street, London, E1 7HT, UK.*
Email: shoaibur.fin.du@gmail.com
[7]*Centre for Islamic Finance, University of Bolton, Bolton BL3 5AB, UK.*
Email: fr7bbs@bolton.ac.uk

(+ Corresponding author)

Article History
Received: 30 January 2025
Revised: 4 March 2025
Accepted: 12 March 2025
Published: 20 March 2025

Keywords
Digital transformation
Emerging technologies
Operational efficiency
Supply chain management.

ABSTRACT

The main objectives of the study are to provide a comprehensive overview of emerging technological solutions, their applications, and their impacts on supply chain digital transformation. It is qualitative research, and secondary data were collected. The study identified five effective applications of the individual solutions. AI provides effective insights, demand forecasting, warehouse automation, transportation and route optimization, supplier selection and management, and predictive maintenance. Blockchain enables tracking and transparency, enhancing traceability, cutting down on counterfeiting, encouraging sustainable and ethical sourcing, and facilitating smart payments. Business intelligence ensures improved communication, monitoring expenses, inventory management, tracking key performance indicators, and optimized visualization. Data science facilitates demand prediction, route enhancement, inventory management, hazard assessment, and supplier administration. IoT enables shipment and delivery tracking, warehouse capacity monitoring, inventory management, storage condition monitoring, and routine optimization and automation. RFID is effective for warehouse management, inventory management, freight transportation, supply chain visibility, and retail management. These emerging technologies collectively promote a more integrated, adaptable, and resilient supply chain landscape, address significant challenges, and open doors to future innovations. The results suggest that by adopting all emerging technologies within the supply chain context, business executives would increase their efficiency and enhance firm value as well.

Contribution/Originality: The study highlights how the emerging technologies complementing each other in digital transformation. It also shows where and how these technologies are used so that the users can get an overview of the applications.

1. INTRODUCTION

Recent years have seen a dramatic shift in supply chain dynamics due to the advent of Industry 4.0 and its range of revolutionary technologies, including the Internet of Things (IoT), blockchain (BC), big data analytics, and artificial intelligence (AI). New paradigms, such as digital transformation and Industry 4.0, are transforming supply chain management operations in business sectors (Sahoo, Kumar, & Upadhyay, 2023). The seamless movement of products and services across long distances has always been made possible by supply chains, which have served as the basis of global trade. Industry 4.0 has facilitated improved supply chain management through the emergence of new digital technologies (Galati & Bigliardi, 2019). However, the rise of emergent technologies is not just revolutionizing the way supply chains operate but also promising a future of transformation and efficiency. These technologies hold the potential to reshape supply chains, inspiring a future where efficiency and transparency are the norm (Attaran, 2020). The supply chain can benefit significantly from digitalization, including better inventory management, real-time data collection, optimization of logistics practices, and enhanced information availability (Bigliardi, Filippelli, Petroni, & Tagliente, 2022). Blockchain, for example, can offer a safe and transparent medium for monitoring the origin of products, thereby guaranteeing the quality and safety of food. Additionally, blockchain can encourage the development of trust and mitigate the risk of fraud by enabling the seamless collaboration of supply chain stakeholders (Attaran, 2020). Emerging technologies are transforming the supply chain and ensuring a future of efficiency and transformation. These are merely a few instances of emerging technologies transforming the supply chain and indicating a future of efficiency and transformation.

Along with the rise of new technologies, there is a greater focus on being environmentally friendly. To boost their efficiency, innovation management, and corporate growth, businesses have put in more effort to become more sustainable. Additionally, they wanted to improve their position in the marketplace and gain a significant edge over their competitors (Schmidt & Wagner, 2019). Organizations must be equipped to confront the obstacles and opportunities that these emergent technologies present as supply chains become increasingly digitized. The adoption of a digital transformation paradigm is not only essential but also mandatory, as it enables organizations to remain agile and responsive in the presence of market challenges (Hartley & Sawaya, 2019). Digitally driven organizations have transcended many conventional supply chains (Verhoef et al., 2021). Supply chains were changed after COVID-19 broke out, which affected the whole world. During this circumstance, companies with more resilient supply chains had a more significant edge over their competitors (Li, Zhang, & Liu, 2022; Sarkis, 2020).

Prior studies examined the impact of digital transformation on supply chain management. Lerman, Smith, and Zhang (2024) investigated how digital transformation in supply chains supports firms' social and economic performance in emerging markets. Akbari, Nguyen, and Le (2024) showed how digital technologies are changing the supply chain landscape in Vietnam by embracing industry 4.0 technologies. The adoption of specific technologies and the relationship between sustainable supply chain management and digital transformation were examined by Stroumpoulis and Kopanaki (2022) and a conceptual framework was developed to better explain how the combination could result in the development of sustainable performances. AlMulhim (2021) looked into how smart technologies are an important part of building the link between digital transformation and firm performance. Despite digital transformation's evident and substantial impact on companies, these advancements have received relatively little academic attention. In recent years, scholars have only recently begun investigating the domains of digitization, digitalization, and digital transformation (Gao, Li, & Wang, 2022).

Therefore, an analysis of the existing research showed a significant gap that looked at the interaction between emerging technologies and digital transformation in the supply chain context. Thus, an in-depth study is needed to clearly show how important new technologies are in bringing automation to supply chain activities. Therefore, to address this need, this study aims to give an in-depth understanding of these technological advances, how they can be implemented, and how they influence the digital transformation of the supply chain. Thus, this study provides insight into the role of new technologies (AI, IoT, BC, BI) in supply chain digitalization and identifies the challenges that companies must confront. It helps academics and practitioners grasp the potential of digitization for firms and management in supply chains. Thus, the study can serve as a foundation for using and analyzing emerging technologies and future research.

This paper is organized as follows. The current discourse regarding emerging technologies that are presently in use is reviewed in Section 2. The application of these technologies in supply chain management is discussed in Section 3, while the benefits of incorporating them into supply chain management are presented in Section 4. In Section 5, several successful case studies are presented and discussed. Section 6 concludes by emphasizing the implications and opportunities for future research and some of the study's limitations.

2. EMERGING TECHNOLOGIES

Industry 4.0 has fostered the development of innovative technologies that have created novel potential for business growth. Supply chains are altered by these technologies, which accelerate the development of unique value-generating methods (Arenkov, Ivanov, & Pavlov, 2019). This section highlights some such emerging technologies.

2.1. Artificial Intelligence (AI)

Numerous sectors have recently shown a growing interest in the potential applications of artificial intelligence (AI) technology (Dubey, Gunasekaran, & Childe, 2020). Artificial Intelligence (AI) denotes the capacity of machines to acquire knowledge from experience and make decisions similar to human intelligence (Duan, Edwards, & Dwivedi, 2019). Rapid advancements and increased attention to AI began in the early 2000s, and the field has since been reconsidered in both research and practical settings (Helo & Hao, 2022). Recently, AI has been growing and becoming more and more popular. This is due to several organizational and environmental factors, such as changing customer requirements, fierce global competition, companies going digital overall, and the fast-paced evolution of technology (Dubey et al., 2020).

AI has made the most essential progress in information technology through its unique ability to perceive and think. AI can be used for numerous purposes, such as computer vision, speech and voice recognition, robotic process automation, machine learning, and deep learning (Sharma, Singh, & Gupta, 2022). The COVID-19 pandemic demonstrated the vulnerability of global supply chains since they depend on many suppliers in different places and have longer physical flows. As a result, stakeholders' needs for resilience, agility, and flexibility have grown significantly. This calls for supply chain management systems that incorporate AI. It is used in almost every area of supply chain decision-making. For example, AI is used to predict supply chain risks (Baryannis, Validi, & Nivolianitou, 2019) to predict fashion trends using logistic regression (Chakraborty, Choudhury, & Tiwari, 2020) to predict back-order scenarios in the supply chain using gradient-boosting machine-learning techniques (Islam & Amin, 2020) to forecast (Nguyen, Phan, & Le, 2021) and to analyze how machines break down (Okabe & Otsuka, 2021).

2.2. Blockchain Technology (BT)

Crosby, Pattanayak, Verma, and Kalyanaraman (2016) define blockchain technology (BT) as a distributed database comprising records or shared public/private records of all digital transactions conducted and disseminated among participating agents in the blockchain network. Four primary qualities make BT different from other information systems: non-localization, security, auditability, and smart execution (Saberi, Kouhizadeh, Sarkis, & Shen, 2019). BT could help move products and processes in the supply chain. Any data could be attached to the item to connect the real item to its digital character in the blockchain (Abeyratne & Monfared, 2016). By connecting these two things, blockchain can help supply chains find fraudulent suppliers and fake goods since only authorized partners can record data. BT could also make information secure and unalterable, which means that it cannot be changed without the permission of the right people. This would stop cheating. Besides these things, blockchain could help the environment by reducing and managing the need for recalls and rework in the supply chain (Saberi et al., 2019).

As a result, BT might improve the control of the supply chain. By simplifying the supply chains, it is possible to follow goods from the chain's beginning to the customer's end. This stops waste, fraud, and other improper conduct. It may also inform people more about how a product is made and shipped so they can choose products that are better for the environment (Stroumpoulis & Kopanaki, 2022).

2.3. Business Intelligence (BI)

The word "business intelligence" is usually used as a generic term for a system (Shollo & Kautz, 2010) or a set of ideas and methods (Sabherwal & Becerra-Fernandez, 2013) that help people make better decisions by using reality support networks. In research, terms like "business intelligence," "business analytics," and "big data" are often used to refer to the identical phenomenon. Some authors have called business intelligence "a process and a brand" (Jourdan, Rainer, & Klein, 2008) "a process, a brand and a combination of methods, or a mixture of such" (Shollo & Kautz, 2010) and "a good or service alone" (Seddon, Constantinides, & Tzuo, 2017).

Furthermore, according to Wieder and Ossimitz (2015) BI is an analytical, technology-supported process that accumulates and analyses scattered business and market data to reveal an organization's goals, prospects, and positioning. BI tools are BI software that is deployed in an organization, and BI solution is a collection of tools and related technologies, applications, and processes used to support BI goals. Business intelligence integrates all news sources. It transforms operational data from the enterprise's resource planning system into actionable insight that supports strategic goals (Al-Mobaideen, 2014). Companies of all sizes use BI tools. They are getting more and more popular. They help businesses make all kinds of decisions, from short-term to long-term ones. BI can be seen as a shield that keeps companies safe and a set of best practices and tools that let top leaders access and analyze company data and turn it into information, they can use promptly to make decisions (Ragazou, Apostolou, & Karampinis, 2023).

2.4. Data Science (DS)

Data science is an area of knowledge that gives decision-makers predictive and statistical tools. It is also an effective way to run organizations from a data-driven viewpoint. DS needs a lot of different skills, like computer science, machine learning, predictive analytics, data-driven methods, and statistics (Kotu & Deshpande, 2019; Waller & Fawcett, 2013). In contrast to business data analytics, which is about gathering, storing, and analyzing data, data science is about more complicated data analytics. This mainly focuses on forecast analytics, like machine learning and deep learning algorithms. Methodologically, data science and business data analytics help supply chain managers make choices at the strategic, tactical, and daily levels. Businesses can gain a competitive edge using data science and business data analytics (Kamley, Prakash, & Karan, 2016). By lowering costs, making supply chains more sustainable, lowering risk, and making them more resilient (Baryannis et al., 2019) data science and business data analytics techniques also help companies better understand what customers want and predict market trends (Hribar, Pucihar, & Rajh, 2019).

2.5. The Internet of Things (IoT)

International literature has a lot of different meanings for the Internet of Things (IoT). Because IoT is a combination of two words and meanings, "Internet" and "Things," the scenario arises (Atzori, Iera, & Morabito, 2010). The term and concept of the Internet of Things (IoT) encompass a variety of disciplines and aspects associated with extending the Internet and the web to physical devices. Miorandi, Sicari, De Pellegrini, and Chlamtac (2012) assert that the Internet of Things (IoT) aims to establish a future in which digital and physical entities can be connected to generate new business opportunities. Therefore, the Internet of Things (IoT) is a novel information technology that is currently in the process of being developed. The technology framework has not yet been fully developed, and an integrated, standard structure has yet to be developed (Wu, Ma, & Zhao, 2021).

Using standard communication, the Internet of Things (IoT) links physical objects to the digital world, like sensors, pumps, thermometers, and RFID tags (Wortmann & Flüchter, 2015). Sensor-based technology in the IoT makes it possible for all players in a supply chain to share information over the Internet. As suggested by Tu, Liu, and Li (2018) IoT should be implemented within supply chain transportation systems. The proposed system would be able to monitor products throughout the supply chain. Furthermore, the Internet of Things (IoT) has the potential to enable stakeholders to participate in the decision-making process by providing them with real-time information (Rezaei, Ortt, & Roodhooft, 2017). The IoT could also improve food supply chains by facilitating the exchange of information with stakeholders and providing a continuous monitoring system (Tagarakis, Andriani, & Sideris, 2021).

2.6. Radio Frequency Identification (RFID)

A key device that is widely used and seen as necessary for the IoT is radio frequency identification (RFID). It has three main parts: an RFID tag, which is made up of a chip and an antenna; a reader, which sends radio signals and gets responses from tags; and middleware, which connects RFID hardware to business applications (Sarac, Abolhasani, & Syntetos, 2010). As companies become more digital, RFID helps them do so by allowing a common framework across businesses, superior compatibility with IT systems, ease of use, and collaboration between functional areas (Kamble, Gunasekaran, & Sharma, 2019). RFID helps digitize supply chains because it creates data from sensors that can be analyzed to find ways to automate and improve processes. RFID technology works by detecting when an item is nearby, recording data, and then storing that data (Musa & Dabo, 2016). System data analysis produces data-driven ideas that help with optimization decision-making (Fanti, Gabbrielli, & Pappalardo, 2017). RFID offers real-time data that boosts overall efficiency and accuracy, which can help increase inventory levels, shorten delivery routes, and improve the customer experience (Choi, Rogers, & Vakil, 2018).

2.7. Robotics and Automation

Due to the need for faster and more efficient supply chains, robotics and automation have become crucial supply chain management technologies. Robotics and automation increase supply chain management by lowering long-term costs, increasing work and usage strength, reducing errors, minimizing repetitive inventory checks, updating orchestration, managing times, and assembling induction to risky and problematic areas (Mohan Banur, Patle, & Pawar, 2024). Advanced robotics is a common way to improve efficiency in warehousing and manufacturing tasks like picking and packaging, welding, and inspection (Krueger, Sutherland, & Rohn, 2016). It eliminates the need for complex, repetitive work, lowers costs, saves energy, and creates a safer, healthier workplace (Ganesan, Gupta, & Kumar, 2017). As automation rises, fewer workers are needed to do routine duties, which lowers emissions and saves energy (Moglia, Alvarez, & Marquez, 2021).

3. EMERGING TECHNOLOGIES IN SUPPLY CHAIN MANAGEMENT

3.1. AI Application in Supply Chain Management

Over the past few years, AI has revolutionized SCM by increasing the effectiveness and efficiency of supply chains at lower costs and with better information. The application of AI in various aspects of the supply chain enables organizations to handle the competitiveness of today's approaches. Some of the areas where AI is proving highly beneficial include demand planning, warehouse management, transportation and routing solutions, supplier identification, and predictive maintenance. This paper will discuss these applications in detail, with real-life data and case studies to show how pragmatic AI is for SCM.

3.1.1. Demand Forecasting

Demand forecasting is one of the most crucial aspects of SCM and a key application of AI in the field. It is essential to accurately forecast future needs to ensure the company purchases the right inventory to meet clients' demands.

Traditional forecasting methods rely on general trends and statistical models, but these approaches often fail to account for market fluctuations, social changes, global crises, or other disasters.

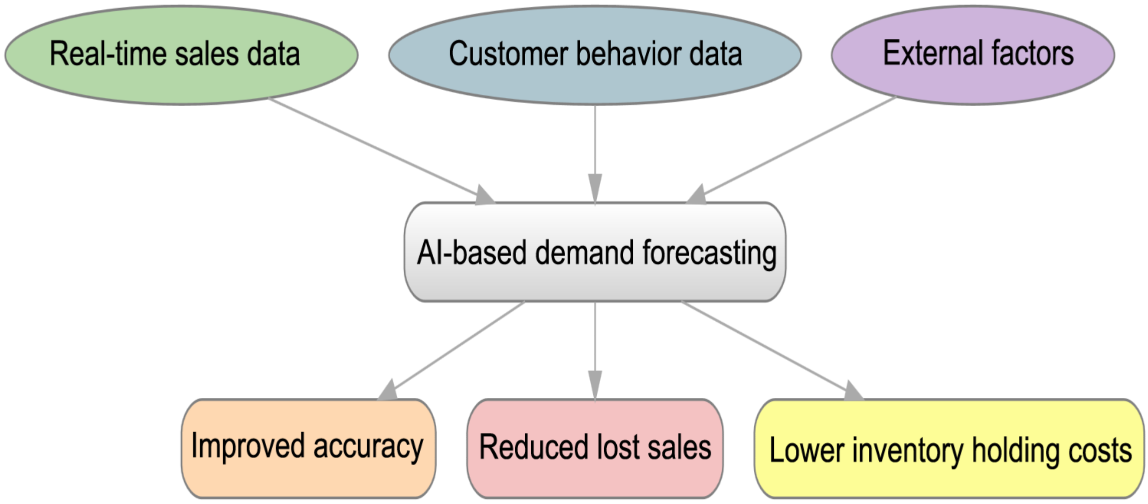

Figure 1. AI enhances demand forecasting accuracy with real-time data integration.

Figure 1 shows how AI criteria for demand forecasting are used to consider sales information, characteristics of potential buyers, and external conditions to enhance the reliability of the forecast, minimize lost sales, and minimize holding costs. Businesses can more readily forecast demand by leveraging algorithms, thus making the right decisions about inventory, all of which lead to better business operations and costs.

AI-based demand forecasting models surpass traditional methods by analyzing large amounts of data, including current sales data, customer behavior, and external factors like macroeconomic conditions and weather (see Figure 1). These models use machine learning techniques to detect patterns and trends that human or traditional statistical models may not recognize.

As stated in a McKinsey report, AI-driven demand forecasting models can reduce absolute forecast error by as much as 50%, leading to significant cost benefits in operations. Specifically, companies can reduce lost sales by 65% and cut inventory holding costs by 10-15%, avoiding both stockouts and overstock situations (McKinsey & Company, 2021). For instance, Amazon is a prime example of a company that uses AI to manage its stock and predict product demand across its numerous outlets. With AI, Amazon can predict network load during peak periods, such as the end of the year, ensuring that hubs with popular products are prepared for increased sales (McKinsey & Company, 2021).

3.1.2. Warehouse Automation

Technology applications in warehousing have also seen a major boost with the integration of artificial intelligence in automated warehousing. In most conventional warehousing processes, like order picking, packing, and order moving, activities are done through human effort and thus are characterized by physical complexities, high costs, and many handling errors. Autonomous mobile robots, AGVs, mechanization, or a combination have radically changed warehouse operations as several activities are becoming automated.

The application of AI technology in the warehouse has dramatically improved efficiency and reduced operational costs. For instance, in its report, Deloitte highlighted that firms implementing AI-based automation systems had reduced labor costs by 70% (Deloitte, 2020a). AI-run robots can work around the clock, which means order deliveries will be completed ahead of time compared to manned workers.

Ocado is the best example of how AI is yielding incredible efficiency in the warehousing sector of online selling companies. For example, Ocado deploys AI to deliver over 222,000 orders weekly without the participation of employees. These robots are mainly used for picking and packing groceries within a system that is highly integrated and mechanically engineered for efficiency in space and time within a warehouse (Meticulous Research, 2024). Moreover, through AI-operated drones, real-time stock checks and monitoring of the storage conditions of the products are done to ensure proper conditions before sale.

3.1.3. Transportation and Route Optimization

Transportation and logistics are some of the critical areas within the supply chain that have benefited from the use of artificial intelligence. AI can be used to adjust transportation routes based on factors such as traffic congestion, weather conditions, fuel prices, and delivery times. By applying predictive analytics, AI can help decrease fuel expenditure, optimize delivery times, and reduce transportation expenses.

According to Capgemini, companies that have integrated AI for route optimization saved between 10 to 30% on logistics costs and experienced delivery times that were 15 to 25% faster (Capgemini Research Institute, 2020). A prime example of AI's application in transportation is UPS's On-Road Integrated Optimization and Navigation (ORION) system. ORION uses AI to calculate millions of data points, including GPS data and specifics related to parcel deliveries, in order to find the most efficient routes for delivery trucks. This system has helped UPS reduce more than 100,000 metric tons of carbon emissions and save over 10 million gallons of fuel annually.

Not only does improving transportation routes lead to increased efficiency and reduced costs, but it also makes organizations more environmentally friendly. Real-time data processing prevents companies from suffering delays and disruptions, making the supply chain more responsive.

3.1.4. Supplier Selection and Management

Another area in SCM where AI has been most pertinent is the supplier selection process. Traditionally, supplier selection was a function that was not very integrated with its counterparts, and the primary inputs at its disposal were cost lead time, and performance. AI is disrupting this process by enabling firms to analyze multiple information vectors on suppliers, their performance, financial standing, sustainable operations, and risks.

The absorption of information about the chosen suppliers is facilitated using advanced intelligent management systems to enhance decision-making. A study by Gartner revealed that firms that implement AI in supply chain procurement for supplier identification and handling achieved a 30% improvement in supplier performance and a 40% reduction in supply chain disruptions (Gartner, 2022a). For instance, Siemens has installed a system that determines supplier credentials for sustainability compliance with the company's high environmental and ethical requirements. With the use of AI, Siemens can effectively monitor the performance of its suppliers and identify risks, including if the supplier has become insolvent or is unwilling or unable to meet environmental standards.

Supplier management is another function that the utilization of AI significantly improves, with unique new standards of cooperation between purchasing organizations and their suppliers. Supply chain visibility leads to better supplier relations because the company can often get real-time data on the supplier, making it easier to negotiate with them.

3.1.5. Predictive Maintenance

Predictive maintenance is one of the most effective AI applications in supply chain management, particularly for companies with large and complex manufacturing and distribution systems. Traditionally, maintenance has been classified as 'breakdown' maintenance, where equipment is only repaired when it fails. This approach often leads to high downtime, production delays, and unplanned repairs.

AI-powered predictive maintenance involves real-time monitoring of equipment conditions using sensors to predict performance. By analyzing this data, AI can determine when equipment is likely to fail, allowing maintenance to be performed before a failure occurs. This highly efficient maintenance strategy reduces repair costs and prolongs the useful life of the equipment.

IBM (2021) revealed that companies that implemented AI-based predictive maintenance reduced unplanned downtime by half and cut maintenance costs by one-third. For example, GE uses AI to control its industrial systems, such as turbines and engines. Predictive analytics help GE identify potential failures and schedule maintenance at times when it will cause the least impact on business operations (IBM, 2021).

Additionally, AI-powered predictive maintenance helps conserve energy demand and enhances the operational life of equipment, playing a crucial role in corporate sustainability initiatives. By applying the concept of relative loss, organizations that adopt predictive maintenance can run their operations in a more sustainable way while using fewer resources.

3.2. Blockchain in Supply Chain Management

Blockchain is an open distributed database that stores transactions so that any changes cannot be made afterward. Due to the properties of immutability, transparency, and decentralization, blockchain can become effective in solving a large number of issues in supply chain management (SCM). Blockchain in SCM is even said to offer improved tracking and control over products, more excellent product provenance, limited counterfeiting, increased sustainability, ethical sourcing, innovative contract payments, and more (see Figure 2). This section then provides a critical review of the use of blockchain in the above-discussed areas of supply chain management.

3.2.1. Tracking and Transparency

The traditional element questioned in SCM is the opacity observed in most supply chain networks. Blockchain solves this problem by creating a private ledger that records all transactions and processes in a blockchain. The consensus among all the parties in the chain is that each link in the supply chain, from raw materials and processing to distribution and delivery of the final product, is documented on blockchain technology for every stakeholder interested in the supply chain to verify. This enhances responsibility and enables different companies in the chain to trace merchandise as it flows through the channel in real-time.

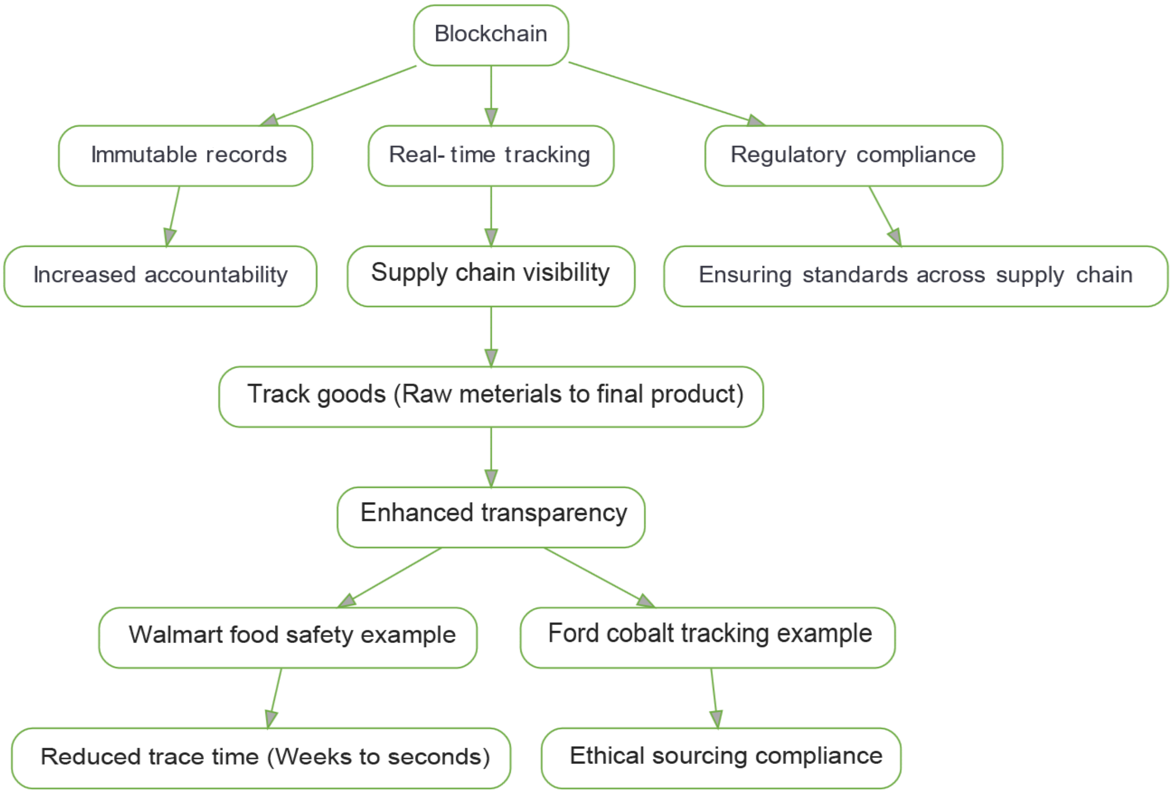

Figure 2. Blockchain enhances supply chain transparency, visibility, and ethical compliance across industries.

The Figure 2 shows how blockchain improves supply chain transparency by enabling real-time tracking, creating immutable records, and ensuring regulatory compliance. This enhances accountability and visibility from raw materials to the final product, with examples like Walmart's food safety traceability and Ford's ethical cobalt sourcing.

A Deloitte (2020b) report pointed out that since blockchain has a decentralized, shared ledger that records every transaction, it dramatically improves supply chain transparency. For instance, blockchain has been applied in the food industry to handle produce and identify its origin and safety standards before reaching the consumer's table. Walmart Inc., in collaboration with IBM, incorporated blockchain in tracing their suppliers of leafy greens, and it took only seconds to trace the source of contaminated production compared with weeks (Deloitte, 2020b).

In car production, Ford has adopted blockchain to monitor cobalt flow, a material crucial to rechargeable batteries. Blockchain also helps Ford trace that cobalt is mined from specific regions free from conflict, thus passing the ethical standards accrued (Ford Motor Company, 2021). These use cases demonstrate how blockchain can increase the clarity of the process, speed up operations, and meet legislative requirements.

3.2.2. Enhancing Traceability

Blockchain enhances Traceability foundationally and principally, allowing companies to track products or raw materials from manufacturers to consumers. This is especially relevant in industries where product security is a concern, such as drug and food supply chains.

A McKinsey & Company (2021b) suggests that applying Traceability through blockchain in the pharmaceutical sector also prevents the distribution of counterfeit drugs, which cost about $200 billion worldwide. Using blockchain to track pharmaceuticals keeps fake products from reaching consumers while authentic products are granted easier access. With the food supply chain being among the most essential, blockchain blocks every aspect of food. Nestlé and Unilever, among other firms, have implemented it to enhance food safety.

Blockchain also facilitates traceability solutions for luxury goods such as diamonds. To address the issues of conflict-free and ethically sourced diamonds, the De Beers group has created the Tracr blockchain platform (De Beers, 2020). It helps maintain customer confidence and curbs the cycles of so-called conflict diamonds.

3.2.3. Cutting Down on Counterfeiting

Piracy has become a significant problem in supply chains worldwide, specifically in fashion accessories, medicines, and technology products. Blockchain's permanency means that it can't be altered once a trade has been made, confirming its genuineness.

According to the World Economic Forum (2021), global counterfeiting costs about 2.8 trillion US dollars annually. Counterfeiting is eliminated through the help of blockchain since every single product can be given a unique number. This identifier, stored in the blockchain, enables consumers and businesses to check the product's genuineness throughout its lifecycle.

Specifically, within the luxury products sector, Aura, developed by the luxury goods giant LVMH (Moët Hennessy Louis Vuitton), allows consumers to clearly check the origins of luxury goods using blockchain solutions. Aura captures each interaction a product has through each phase of its lifecycle, from material acquisition to end-use, guaranteeing the authenticity of product supplies and stopping counterfeit products from reaching the end user (LVMH, 2020).

In the pharmaceutical industry, blockchain makes it possible to effectively stop counterfeit drugs from circulating through the market by documenting transactions and movement through the supply chain. Pfizer and Merck recently partnered to utilize blockchain to verify medicines and prevent counterfeiting that poses financial and reputational damage to companies like Pfizer (Pfizer, 2021a).

3.2.4. Encouraging Sustainable and Ethical Sourcing

Environmentalism and social responsibility remain high among consumers, shareholders, and governments. Blockchain makes it possible to track products' environmental and social effects practically in real time as they journey through the supply chain.

Consequently, the Gartner (2022b) study revealed that sustainability was a key concern in supply chain management, with 90% of consumers demanding sustainably produced products. Blockchain guarantees that organizations can validate assertions about sustainability and sourcing concerning products and services by establishing credibility.

It applies blockchain technology to the supply tracking of palm oil to promote sustainability and socially responsible production. It sources palm oil from the plantations by asking blockchain technology providers to track its journey from the plantation to the finished product while discouraging deforestation and ensuring fair labor practices for employees (Unilever, 2021).

Blockchain also enhances the circular economy by tracking and tracing products through recycling and disposal across various value chains. For example, companies like Coca-Cola are already using blockchain to explore the possibilities of increasing their efficiency in recycling bottles and packaging materials (Coca-Cola, 2020). It also helps in waste management and makes the company look environmentally friendly in the eyes of the customer.

3.2.5. Smart Payments

Smart contracts use blockchain to automate the payment process. According to a PwC (2021) estimate, smart payments related to blockchain decrease the cost of transactions by 30-50%, especially in cross-border payments where multiple parties like banks and payment processors complicate the flow and charge additional fees (see Figure 3).

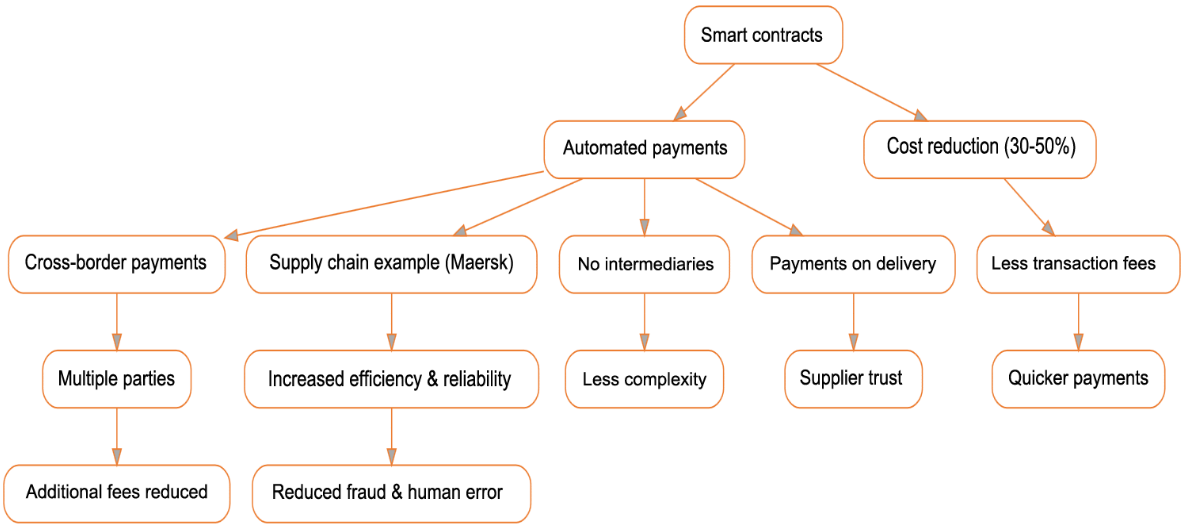

Figure 3. How smart contracts revolutionize payments with blockchain for cost efficiency'.

In the Figure 3, intelligent contracts facilitate and reduce them by 30-50% while eliminating potential buyer characteristics effectiveness, especially in cross-border forecasts' reliability. The advantages include faster payments and lower charges, besides enabling suppliers to gain much-needed trust.

Smart contracts—digital contracts written in code that automatically execute based on parameters set out in the code—make intermediaries obsolete by cutting out the time and cost of a basic payment system. In supply chains, intelligent payments guarantee that suppliers receive payment once predefined conditions are fulfilled, such as the delivery of goods or the achievement of a specific target.

Maersk, one of the world's biggest international shipping companies, currently uses blockchain in the payment process for its shipment services. With smart contracts, Maersk guarantees payments to be made immediately upon product delivery, thus increasing reliability and efficiency between buyers and sellers (Maersk, 2020). This also reduces fraud and human error likely to disrupt the general supply chain, promoting innovative blockchain payments.

3.3. Business Intelligence in Supply Chain Management

BI is one of the most essential tools in SCM since it provides timely information to enhance decision-making and facilitate operations. In the contemporary world, where data is a precious resource, firms use BI tools to gain a competitive advantage, improve their performance, and realize the optimum use of their resources. Managing a supply chain is enhanced through BI with the benefits of communication improvements, tracking of costs, inventory control, key performance indicators (KPIs), and visual display improvement (see Figure 4). This section evaluates BI in SCM based on empirical data and real-life experiences of organizations.

3.3.1. Communication

It is essential to have proper information flows between different levels of the supply chain to support the goal of this concept. Advanced BI tools generate real-time data that optimize interactions between suppliers, manufacturers, and retailers. In organizations with centralized data systems, BI allows increased collaboration, breaks down silos, and ensures that the right people are getting the correct information.

Langlois and Chauvel (2017) have identified that companies that apply BI to enhance communication with their supply chains recorded a 20% decrease in operation delays. The automotive industry has adopted BI tools, especially in communication between suppliers and manufacturing plants. In addition to the above, Toyota has minimized production delays through real-time working updates on the quantity of available parts and delivery schedules (Langlois & Chauvel, 2017).

BI tools like Tableau and MS Power BI offer dashboard features through which users and their teams can grab information in the form of stories and make decisions. As Davenport and Harris (2017) rightly pointed out, it has been estimated that organizations that use BI for communication can solve problems 40% faster than organizations that don't use business intelligence for communication. Most importantly, it helps reveal inter-departmental dependencies and improve collaboration, thus delivering a flexible supply chain.

3.3.2. Monitoring Expenses

Most functions of SCM involve cost control, as most expenses will influence the firm's profit. Business Intelligence offers features to monitor expenses in real time and help detect flaws, avoiding unnecessary expenditures. Some areas where an organization can implement it are transportation costs, procurement expenses, warehousing fees, and so on.

Accenture (2020a) report states that businesses that conduct BI on expenses have noted cost-cutting of up to 25%. For example, Procter & Gamble uses BI to manage spending within its global supply chain operations. By tracking the costs of transport and logistics solutions, P&G saw the options for choosing optimal routes when it came to fuel expenditure that was closely trimmed down (Accenture, 2020b).

Furthermore, new BI tools like SAP HANA enable the analysis of operational and financial costs within a single system. They also help improve the efficiency of budget preparation, leading to better financial control in these firms' supply chain operations. A study by Caserio and Trucco (2018) identifies that organizations employing BI for controlling expenses are 30% more likely to meet their cost-cutting objectives than the average.

3.3.3. Inventory Management

Inventory management is one of the areas that undergoes a massive transformation under the influence of Business Intelligence. BI tools allow companies to monitor and track their inventory levels, ensuring they get the right stock at the right time and avoid overstocking and stock shortages. The right positioning of stored stock must be done efficiently to avoid high holding costs while ensuring a constant flow of goods.

As noted by Fawcett, Magnan, and McCarter (2008) organizations that have adopted BI for order management can decrease inventories by as much as 15–30 percent and increase order satisfaction by up to 25 percent. For instance, BI and predictive analyses help the world's largest online retailer, Amazon, track and organize its inventory. To do this, Amazon organizes and analyzes customers' perceived demand and other past data to fashion its supply so that there will be no stock-out situations or excessively high inventories in its warehouses.

QlikView is one of the BI tools that helps determine how and when a particular product's inventory is sold, which product is selling very fast, or which is actually stagnant. This helps supply chain managers decide when to reorder, reduce prices for certain products, or stop offering them altogether. As Sherman (2014) stated, many firms that adopted BI for inventory management decreased their holding costs by 20 percent, enhancing the business's viability.

3.3.4. Monitoring Organization's Key Performance Indicators

KPIs (Key Performance Indicators) are imperative to track performance efficiency in supply chain management. Business Intelligence tools keep all the KPI parameters in a real-time application, allowing companies to monitor performance and take corrective action if necessary. Typical measures for evaluating SCM performance include order fulfillment percentage, transportation expenses, time needed to complete an order, and supplier quality.

According to a Gartner (2021b) companies that used BI to monitor supply chain KPIs experienced a 15% enhancement in operational efficiency. Coca-Cola uses BI to manage its key performance indicators affecting its supply chain operations globally, improving efficiency, delivery time, and customer satisfaction. This has helped maintain high service levels while reducing operating expenses (Gartner, 2021b).

Enterprise BI systems like IBM Cognos Analytics enable firms to define personalized views of KPIs, showing them in real-time on specific dashboards. These metrics can be used to determine critical elements of workflow, such as constraints, problems, and opportunities for improvement. Jafari, Zarei, Azar, and Moghaddam (2023) state that enterprises that monitor KPIs with the help of BI are 35% more likely to reach their performance targets than those that track performance metrics using traditional tools.

3.3.5. Optimized Visualization

The use of Business Intelligence tools has been found to enhance the optimal presentation of big data. Different visualization tools help supply chain managers make sense of large datasets, which can be helpful when making different decisions. Data visualization makes it easier for businesses to identify complex patterns that may not easily be seen through simple numbers and figures.

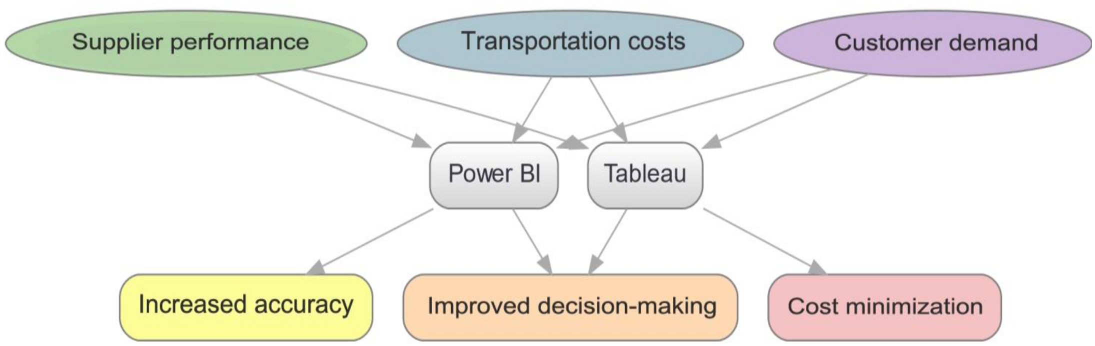

Figure 4. Business intelligence tools enhance supply chain decision making with data.

The Figure 4 shows how business intelligence tools such as Power BI and Tableau, in aspects such as supplier performance data, transport costs, and customer demand data, are helpful in decision-making, accurate, and cost-effective in supply chain management using data visualization.

A study by Khakpour, Colomo-Palacios, and Martini (2021) identified that data visualization tools enhanced decision-making by approximately 28% in supply chain management. Current data used by Unilever includes supplier performance, transportation costs, and customer demand, which are analyzed by Business Intelligence visualization tools. Through visualizations of this data in various dashboards, Unilever's supply chain managers can make beneficial decisions, such as minimizing costs (Khakpour et al., 2021).

Tools like Tableau and Power BI offer powerful visualization capabilities, allowing users to create customized reports and dashboards that cater to their specific needs. These visualizations can be shared across the organization, ensuring that all stakeholders have access to the same data and insights. According to Kirtane et al. (2024) companies that use BI for data visualization see a 20% improvement in decision-making accuracy, as visual insights enable better interpretation of complex data.

3.4. Data Science in Supply Chain Management

In recent years, Data Science has emerged as a critical insight for supply chain management (SCM). Through better data use, managers can forecast demand, optimize carrier selection and inventory management, evaluate risks, and improve supply vendor management. Intelligent techniques help to improve supply chain responsiveness, effectiveness, and ability to recover from disruption. This section overviews the transformations introduced by data science into each of these areas and provides case evidence and statistical data.

3.4.1. Demand Prediction

One key idea is demanding prediction to achieve supply chain responsiveness and flexibility in operations. Historically, forecasting consumer behavior and market trends was highly basic, using statistical models to identify future trends based on past data. Recent advancements in big data analysis, including the utilization of machine learning (ML), have helped optimize demand forecasting by processing large datasets in real time.

As reported by Feizabadi (2022) the application of machine learning models in demand forecasting increased predictive accuracy by 20–30 percent in the retail industry. These models consider temporal and spatial characteristics, leading customer behaviors, and systematic events (e.g., economic fluctuations or sudden epidemics). Amazon, for example, leverages ML to predict demand to restock goods in the right place and at the right time (Feizabadi, 2022).

Moreover, organizations, including PepsiCo, leverage data science to forecast high sales periods during holidays or events. PepsiCo's application of big data in determining stockout rates involved analyzing social media data, historical sales data, and even weather, which resulted in a 15% reduction in stockout problems (Harvard Business Review, 2020). Demand forecasting models help companies identify over or under-demand, reducing the impact of demand variability.

3.4.2. Route Enhancement

Transportation management is one of the most important functions of supply chain management, especially for organizations with a vast distribution network. In this case, data science provides methods to calculate traffic flow, weather conditions, and delivery timetables so that routes can be designed and fuel expenses minimized.

Anitha and Patil (2018) assessed that transportation costs may decrease by 12–20% through data-driven route optimization. For example, UPS applies analytical methods to optimize delivery routes. Through its ORION (On-Road Integrated Optimization and Navigation) system, UPS identifies over 250 million data points daily, saving 10 million gallons of fuel every year (Anitha & Patil, 2018). Applying data science to improve routes is critical to optimizing costs and addressing environmental concerns by eliminating unnecessary movement and emissions.

DHL applies real-time information to switch routes during operations depending on traffic density, barriers, and unfavorable conditions. This has resulted in a 15% improvement in the timely delivery of goods and services and a major decrease in their carbon footprint (DHL, 2022). Data science allows organizations to adapt to new conditions on the ground so that goods are delivered to required locations on time and at reduced costs.

3.4.3. Inventory Management

Another clear example of the use of data science is in inventory management techniques. Therefore, it is important to engage predictive analytics to help companies manage their inventories effectively and in the right way. This results in lower holding costs eliminates stockout incidences and improves customer satisfaction.

According to a report by McKinsey & Company (2021c) business organizations that applied data science in inventory management realized 15–25% reductions while achieving or surpassing service levels. For instance, Walmart employs live analytics to monitor the quantity of products in its stores and estimate demand, leading to better restocking and minimal stock loss (McKinsey & Company, 2021c).

Decision-support tools such as ARIMA for demand forecasting and machine learning models enable firms to adapt their inventory holding to demand variability. This is especially crucial for manufacturing firms that deal with perishable commodities like food and drugs since overstocking can result in losses. The big supermarket chain Kroger uses prescriptive analytics for fresher food and has reported a 10–15% reduction in food waste while adequately stocking its stores (Gartner, 2020b).

3.4.4. Hazard Assessment

Conducting a hazard assessment for supply chain risk management is important in industries where disruptions can result in catastrophic consequences. Risk management is another area where data science delivers value by showing businesses what threats might arise, such as hurricanes, failed suppliers, or geopolitical events, and how to avoid them.

Keurulainen (2024) argues that risk analytics and other data science tools can be used to forecast disruptions in their infancy, providing companies with ways to reduce such incidents. For instance, General Motors (GM) employs big data systems to evaluate the risks of failed suppliers and natural calamities. This way, GM has adequate data to alter sourcing strategies and prevent process disruptions, as Keurulainen (2024) recommends.

Additionally, organizations such as IBM have designed predictors that enable them to determine and evaluate the vulnerability of supply chains to climate change. These models assess parameters like weather conditions, infrastructure, and supplier locations to trace risky regions. Implementing this data into companies' supply chain management means that plans can be enhanced, even when some dangers are worth avoiding (IBM, 2020).

3.4.5. Supplier Administration

Supplier management is a sophisticated process that involves managing supplier relationships, supervising contracts, and minimizing risks associated with such partnerships. This is where data science comes in handy: when supplier performance data is analyzed and evaluated for risk, the supplier selection process is improved.

Stefanovic (2014) reported that embracing data science models can enhance supplier performance by 10–15 percent by observing reliability, quality of supply, and delivery performance in real time. For example, Siemens (2021b) deploys data mining in real time to evaluate suppliers' efficiency and reliability. Highlighting delivery times, product quality, and environmental compliance gives Siemens the necessary information to decide which suppliers to work with (Thirumalai, 2014).

Furthermore, data science techniques allow firms to minimize the time spent evaluating potential suppliers. Companies like Intel, for example, apply machine learning approaches to ranking their suppliers according to cost, quality, and risk. This has enhanced the company's supplier evaluation process by 20%, allowing it to work with the right suppliers (Intel, 2021).

3.5. IoT in Supply Chain Management

IoT is one of the pillars that have dramatically impacted SCM through the observation, optimization, and automation of the supply chain. Examples of IoT applications in SCM include shipment tracking, delivery tracking, capacity tracking throughout the warehouse, inventory tracking, storage environment tracking, and routine tracking and automation. With the help of IoT devices and sensors, businesses can gather and analyze data, significantly improving planning and controlling processes. This section discusses IoT contributions based on selected areas of SCM, supported by empirical evidence and case studies.

3.5.1. Shipment and Delivery Tracking

Thanks to advanced IoT, shipments and deliveries can be controlled in real-time, allowing for a better understanding of the entire supply chain process (see Figure 5). Smart tags embedded in the load, trucks, and containers allow continuous tracking of the shipment's location, temperature, humidity, and other aspects.

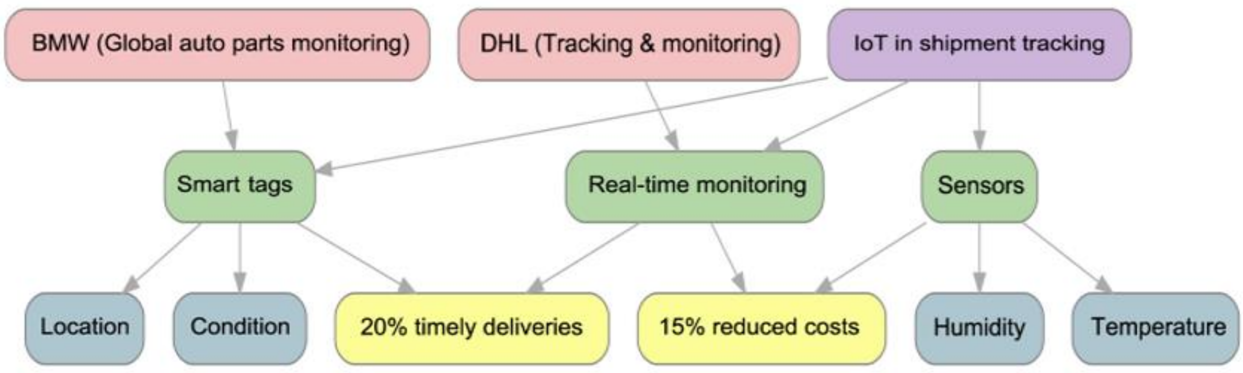

Figure 5. IoT revolutionizes shipment tracking, enhances efficiency and reduces costs.

The Figure 5 demonstrates how IoT-enabled shipment tracking using smart tags and sensors provides real-time monitoring of location, condition, humidity, and temperature. This technology improves timely deliveries by 20% and reduces costs by 15%, as seen in examples from BMW and DH.

A report published by Deloitte in 2021 established that enterprises that embraced the technology with the application of IoT for shipment tracking witnessed a 20% increase in timely deliveries and a 15% decrease in transportation costs. This becomes equally important when time factors, such as health-related products and perishable goods, are critical in production and delivery to customers. For instance, DHL leverages IoT by incorporating tracking devices that monitor consignments' physical condition and location to ensure they arrive in the best condition (Deloitte, 2021b).

Another example of IoT success is the automotive and industrial company BMW, which has installed IoT sensors in its supply chain to monitor the flow of specific auto parts across the globe. Real-time information about the location and status of shipments has helped BMW reduce its supply chain risks and increase efficiency (BMW, 2020). The application of IoT technology helps to make forecasts in shipments to avoid delays resulting from other factors.

3.5.2. Capacity Analysis for Warehouses

One of IoT's most noteworthy applications is in warehouse capacity monitoring. Internet of Things sensors in warehouses include space occupancy, inventory, and product movement within the warehouse. Such information assists firms in managing warehouses by making the best use of space.

McKinsey & Company (2022) showed that IoT utilization for warehouse capacity monitoring reduced warehousing costs by 25% and upgraded inventory turnover by 30%. For instance, Amazon incorporates IoT sensors and robotics in its fulfillment centers to identify the number and location of products in available spaces and optimize storage (McKinsey & Company, 2022). IoT has improved picking and packing performance, making Amazon's order fulfillment faster.

Furthermore, IoT sensors can identify open spaces in warehouses, allowing organizations to enhance space utilization and potentially eliminate the need for new warehouse construction. This is not only cost-effective but also helps control the environmental impact of warehousing.

3.5.3. Inventory Management

As one of the supply chain segments, inventory management is an essential element in which IoT can be helpful. The implementation of IoT sensors facilitates automated measurement of inventories by regularly capturing the quantity and availability of stocks, usage rates, and demand. This, in turn, offers organizations an alternative to holding too much or too little stock, saving on holding costs while enhancing customer satisfaction.

When Accenture (2021) studied an IoT use case for inventory management, businesses reported a decrease in inventory by 15–30 percent without compromising or even potentially improving service quality. Walmart uses IoT sensors and RFID technology to track inventory without physically handling the products, which helps with better restocking and demand estimation (Accenture, 2021). This has helped reduce stockout occurrences, especially during the holiday seasons, negatively affecting customer satisfaction.

IoT devices also support information that can be used to enhance inventory ordering mechanisms. If the amount of stock reaches a low level, the system can order the product to refill the stock and avoid running out of products. Such automation enhances productivity and enables employees to focus on higher value-added roles.

3.5.4. Periodical Check of Storage Conditions

In some industries, the quality of the product is highly influenced by the environment in which it is stored (such as pharmaceuticals, food, and chemicals). IoT sensors monitor the storage environment, including temperature, humidity, and light exposure. Research has established that proper product storage enhances a firm's ability to avoid spoilage while adhering to regulatory requirements.

For instance, Pfizer deploys IoT intelligent temperature sensors in its supply chain to track the conditions to which vaccines are exposed. These sensors provide instant notifications if temperatures exceed the set range necessary for the vaccines to remain potent during transportation and storage (Pfizer, 2021b). Gartner (2020a) identified research stating that firms employing IoT in SCM realized a 20% reduction in spoiled products and a 15% improvement in regulatory compliance.

In the food industry, IoT sensors are used by Nestlé to monitor storage conditions. By ensuring that perishable products are correctly stored, Nestlé has minimized wastage and improved product quality (Gartner, 2020a). This benefits the organization in terms of increased customer satisfaction and helps minimize the environmental impact of supply chain management.

3.5.5. Routine Optimization and Automation

IoT makes it easier to perform routine optimization and automation in SCM by acquiring real-time data on various aspects of the supply chain that can be used to improve processes. Remote equipment can be used to assess the performance of machinery, monitor employee activity, and track the movement of products within the supply chain, identifying potential areas for improvement.

Capgemini (2021) showed that industries leveraging IoT for routine process improvements saw efficiency gains of 20–30%. IoT makes P&G's factories smart by determining equipment parameters and correlating them with the likelihood of failure shortly. This has minimized downtime by 25%, while enhancing overall performance (Capgemini, 2021).

Moreover, IoT enables the automation of repetitive tasks like order selection, packaging, and delivery. Zara has adopted IoT in its depots to increase automation, reduce labor expenses, and expedite order processing (Zara, 2021). With such tasks being automated, Zara has quickly responded to changes in consumer demand, enhancing its competitiveness in the international fast fashion industry.

3.6. RFID in Supply Chain Management

RFID as an application has significantly impacted today's supply chain management (SCM). This technology creates new opportunities for a company to manage its assets, monitor stock, and improve the efficiency of warehouses, logistics, supply chain, and retailing. Drawing on empirical data and pertinent examples, this section critically discusses how RFID can be used in SCM.

3.6.1. Warehouse Management

In warehouse management, RFID technology has significantly changed how organizations manage the flow of goods. With RFID tags and readers applied in warehouses, it is convenient for a company to monitor the position of products in real-time, increasing efficiency and requiring less workforce. Compared to conventional barcode technology, RFID does not require an object to be aimed at directly to be scanned, making object scanning faster and more precise.

Specifically, Accenture (2020b) argued that warehouses employing RFID reduce labor costs by 15–30% while gaining a 25% enhancement in inventory reliability. Amazon uses RFID in its fulfillment centers to track stocks, ensuring faster order processing and minimal picking errors (Accenture, 2020b). The integration of a tracking system to monitor the flow of goods without the need to involve personnel speeds up warehouse operations.

Additionally, RFID systems can easily interface with warehouse management software (WMS) to further enhance inventory tracking activities and arrange the goods in proper storage. For instance, Siemens adopted RFID technology to automate warehouse procedures, reducing the time for product identification and palletizing by 30% (Siemens, 2021a).

3.6.2. Inventory Management

One of the most practical uses of RFID technology is in inventory management. RFID technology makes real-time tracking of products possible, helping businesses achieve efficient stock management and reduce stock surplus. RFID tags differ from barcodes because they can hold significant information and provide the product's location, status, and movement at any given time.

Zebra Technologies (2021) identified that RFID has helped firms improve inventory visibility by 25% while reducing shrinkage by 20% among those that adopted it for inventory control. Walmart has led the way in implementing RFID in its stores and retail distribution centers. Walmart realized that RFID helped cut its inventory costs by 15% and increased shelf inventory accuracy or availability since products were reordered before they ran out of stock (Zebra Technologies, 2021).

Moreover, RFID technology adopted in stores helps perform automatic stock-taking, eliminating the need for physical counts. These audits give the Company real-time information required to update stock periodically. Carrefour, a European retailer, reduces inventory through stock counts over RFID, which cuts the time taken to perform audits by 50% and increases data accuracy (Carrefour, 2020).

3.6.3. Freight Transportation

In freight transportation, RFID increases efficiency by enabling better shipment tracking. RFID tags attached to shipping containers or affixed to each product enable companies to track the status of assets in transit. They also foster high visibility of business operations, facilitate logistics management, reduce transportation costs, and ensure timely delivery.

DHL (2022) reported that RFID technology reduced shipment processing time by 20%, and lost shipments decreased by less than 10%. RFID technology is used by Maersk, a global shipping company that tracks containers in real time. An effective container tracking system provides location updates for items being shipped with Maersk and helps the firm enhance asset turnover, reduce container idle time, and lower shipping costs (DHL, 2022).

RFID also improves the security of freight transport by tracking the state of goods throughout transportation. With the help of RFID sensors, companies can recognize changes in temperature, humidity, or vibration, ensuring that goods are delivered in appropriate conditions. This is especially crucial for industries dealing with products that must meet certain standards, such as pharmaceuticals or food. For example, Pfizer implements RFID technology to track vaccine temperatures during transportation, ensuring proper conditions (Pfizer, 2021a).

3.6.4. Supply Chain Visibility

Supply chain visibility is one of the most important factors in today's complex supply chains. RFID enables real-time tracking of materials and products from raw material suppliers through distributors to customers. This increased visibility allows timely responses to disruptions, optimization of inventory, and improved customer service.

McKinsey & Company (2021d) established that companies applying RFID to increase supply chain visibility saw lead time reduced by 15–20% and on-time delivery increased by 10%. Ford uses RFID systems across its supply chains to monitor the position of strategic components in real-time. This has eliminated production delays and enhanced the firm's capacity to meet client needs (McKinsey & Company, 2021a).

It also helps companies track the performance of suppliers they conduct business with by tracking their suppliers' data in real time. Monitoring the flow of goods from suppliers enables firms to predict bottlenecks in the system accurately and take action to minimize lead time. Unilever applies RFID technology to monitor its suppliers' shipments and avoid potential supply chain disruptions (Unilever, 2020).

3.6.5. Retail Management

RFID has also transformed retail management by providing retailers with real-time visibility into inventory levels, reducing shrinkage, and improving customer service. In retail environments, RFID tags can be used to track individual products, ensuring that shelves are stocked and that customers can easily find what they are looking for.

A report by Gartner (2022c) found that retailers using RFID experienced a 15-30% reduction in shrinkage and a 10% improvement in sales due to better stock visibility. Zara, a global fashion retailer, has implemented RFID in its stores to track inventory in real-time. By providing accurate data on stock levels, Zara ensures that its shelves are always stocked with the right products, reducing stockouts and improving customer satisfaction (Gartner, 2022c).

Additionally, RFID enables faster checkout processes by allowing retailers to scan multiple items at once, reducing wait times for customers. Decathlon, a leading sporting goods retailer, uses RFID to enable self-checkout in its stores. Customers can scan their items with an RFID reader, and the system automatically detects the products and processes the payment. This has improved the customer experience and reduced the time spent in line by 30% (Decathlon, 2021).

3.7. Robotics and Automation in Supply Chain Management

Robotics and automation are essential strategic tools in today's SCM, offering increased efficiency, accuracy, and decreased costs. With technologies like AS/RS, AGVs, collaborative robots, and controls, organizations can reduce worker intervention and increase efficiency. This section critically evaluates the use of robotics and automation in the context of supply chain management, with special consideration given to warehouse management, automation, and supervisory control.

3.7.1. Warehouse Management

There has been tremendous change in warehouse management brought about by robotics and automation. Warehouse management needed manual effort from people in the past, and this is quite a disadvantage since it is time-consuming and prone to errors, thus increasing the cost of running the whole process. Today, robotics has enabled companies to enhance processes, including picking, packing, and inventory control.

Dhaliwal (2020) states that the use of robots in warehouses has helped to act as robots to increase productivity by 30 % while, at the same time, cutting down the costs of human labor by 20%. Amazon is a clear example of this, having implemented the use of robotic arms, as well as mobile robots within its fulfillment centers. These operation robots are companions with human employees to minimize mistakes and enhance order fulfillment (Dhaliwal, 2020).

Awareness can also be constant because robots do not require any rest, thus making the operations in the warehouse efficient. McKinsey & Company (2021e) revealed that firms implementing robotic systems in warehousing cut the processing time by 25% while achieving 15% warehouse efficiency. This level of automation assists businesses in working with increased numbers of products without compromising accuracy and speed (McKinsey & Company, 2021b).

3.7.2. Automated Storage and Retrieval Systems (AS/RS)

Automated Storage and Retrieval Systems are one of the significant categories of warehouse automation systems that find applications in the appropriate picking of stored products, especially those with high cube utilization but requiring low order selection variety. AS/RS systems involve the storage and retrieval of goods and products by manual handling equipment without the intervention of man and, hence, the use of robotic systems to move goods in a particular warehouse. This saves time, helps avoid contact with people, and ensures the compactness of the storage space.

Deloitte (2021a) reported that, companies that employed AS/RS garnered a 40% reduction in storage area footprint and a 30% improvement in throughput. For example, Walmart utilized this technology in its warehouses to enhance stock control. Such systems help Walmart increase the density of specific products while improving efficiency in picking and space search (Deloitte, 2021a).

The use of AS/RS systems also has another advantage: the time it takes to fulfill an order is also reduced. When using automated retrieval systems, Karpova (2022) showed that picking times were reduced to half, thus enabling companies to respond effectively to increased customer demand for expeditious deliveries. Besides, these systems can work in various hostile environments, for example, in refrigerated warehouses where people can work with some constraints (Karpova, 2022).

3.7.3. Automated Guided Vehicles (AGVs)

Automated Guided Vehicles (AGVs) are a standard supply chain technology used to transport materials within a warehouse, factory, and distribution center. Partially automated guided vehicles, or AGVs for short, move along specific tracks that may be marked using sensors, lasers, or magnetic strips, thus reducing the need for human control. These vehicles can lift large loads, which will help eliminate some of the handling equipment, such as forklifts.

Guru, Khan, and Deshmukh (2018) have indicated that companies using AGVs have experienced a 20% decrease in material handling costs and an increase in operational efficiency by 15%, as supported by Bechtsis, Tsolakis, Vlachos, and Iakovou (2017). Toyota employs AGVs in all its manufacturing facilities to move parts from assembly lines to stores. By implementing AGV systems, Toyota has increased the manufacturing productivity of materials and overall workplace safety by automatically handling material movement (Bechtsis et al., 2017).

AGVs also help minimize downtime and enhance safety, which he believes has benefits. Kiva Systems, now a subsidiary of Amazon Robotics, has come up with vehicles that transport shelves of products to employees for packing and sorting. It also cuts the number of hours the workers are required to walk, something that would not be possible with human-operated forklifts (Amazon Robotics, 2021). The AGVs can also be used in highly complicated and dynamic environments. With the increased technological features, they can avoid the obstacles in their path within their working area.

3.7.4. Collaborative Robots (Cobots)

Collaborative robots, or cobots, are designed to work alongside human workers, enhancing productivity without replacing human labor entirely. Unlike traditional industrial robots, which are typically isolated for safety reasons, cobots are equipped with advanced sensors and AI systems that allow them to operate safely in close proximity to people.

A study by Boston Consulting Group (2020) found that the adoption of cobots in supply chains can increase productivity by 20-40%. Cobots can handle repetitive tasks, such as packaging, labeling, or quality control, freeing up human workers to focus on more complex and value-added activities. ABB Robotics has developed cobots that work in automotive supply chains, performing tasks such as assembling small components and checking product quality (Boston Consulting Group, 2020).

Cobots also offer flexibility and scalability. Universal Robots has developed cobots that can be easily programmed to perform a wide range of tasks, making them ideal for small and medium-sized enterprises (SMEs) with varying production needs (Universal Robots, 2021). The collaborative nature of these robots allows companies to scale their operations quickly and adapt to changes in demand without the need for extensive reconfiguration.

3.7.5. Control and Supervision

Robotics and automation in supply chains require sophisticated control systems to ensure that all processes run smoothly and efficiently. Advanced control systems use artificial intelligence (AI) and machine learning (ML) to monitor robotic operations, optimize workflows, and prevent equipment failures. These systems provide real-time data on the performance of robots, enabling companies to make data-driven decisions and improve operational efficiency.

A report by Gartner (2021a) revealed that companies using AI-driven control systems in their supply chains saw a 15-25% improvement in efficiency and a 20% reduction in downtime. Siemens, for example, uses AI-powered control systems to monitor its automated manufacturing plants. These systems analyze data from sensors in real-time, predicting equipment failures before they occur and scheduling maintenance proactively (Gartner, 2021a).

Moreover, AI-driven control systems enable supply chain managers to optimize robotic workflows, ensuring that resources are allocated efficiently. GE Healthcare uses control systems to monitor its robotic systems in real-time, allowing for adjustments to be made dynamically based on demand fluctuations. This has led to a 20% increase in production efficiency and a 15% reduction in lead times (GE Healthcare, 2021).

4. ADVANTAGES OF ADOPTING EMERGING TECHNOLOGIES IN SUPPLY CHAINS

4.1. An Integrated and Resilient Supply Chains

In recent times, there has been a noticeable surge in interest in supply chain resilience, with practitioners and scholars concentrating on creating a supply chain that can withstand unfavourable circumstances (Chatterjee, Chaudhuri, & Vrontis, 2024). Organizations can implement emerging technologies like blockchain (Bayramova, Edwards, & Roberts, 2021; Kurpjuweit, Neumann, & Müller, 2021) Industry 4.0, and artificial intelligence (Birkel &

Müller, 2021) to further enhance the effectiveness and resilience of their sustainable supply chain management (SSCM) concept (Karmaker et al., 2021). To increase the robustness of their SSCs, many businesses would rather go beyond remote monitoring to control, optimization, and sophisticated autonomous AI-based systems. While AI technologies have applications in marketing, logistics, and production, they are also applicable in nearly every other area and subfield within supply chain management (SSCM). These applications include high accuracy, high throughput, and fast issue-solving (Kazancoglu, Ozbiltekin-Pala, Mangla, Kumar, & Kazancoglu, 2023). Adopting I4.0 technologies, often known as IDT of I4.0, offers significant technical advancements that make it possible to integrate real-time supply chain partners and gather and analyze massive amounts of data automatically. Making more precise judgments and enhancing supply chain integration may be facilitated by using more IDT of I4.0, such as cloud computing, big data, and the Internet of Things (IoT) (Oliveira-Dias, Maqueira-Marín, & Moyano-Fuentes, 2022). Additionally, it is predicted that Industry 4.0 technologies powered by ICT would improve process integration, leading to long-term organizational performance. BT is an organizational capacity that unifies all of the resources and assets of SC, enhancing tasks like information sharing, product monitoring, and transaction transparency. In addition to its fundamental advantages, blockchain provides a platform for integrating cutting-edge technology like AI and IoT. To demonstrate how blockchain technology has not only streamlined current procedures but also opened the door for innovative business models and cooperative ecosystems, case studies and experimental projects are investigated (Oriekhoe et al., 2024). BT adds an extra degree of protection against intrusions and data breaches, which often happen through network-level attack vectors, by encrypting all data shared inside a network. Decentralization reduces the risk of a single point of failure, while the traceability feature of a permanent record of all transactions carried out by authorized users in the permissioned network eliminates the threat of insider attacks (from people as an attack vector) (Bayramova et al., 2021). The creation of a digital SC twin, or computerized digital SC model that represents the network state in real-time and enables complete end-to-end SC visibility to strengthen resilience and test contingency plans, is possible with the use of data analytics to enhance the current decision-support tools. For planning and making choices about control in real-time, a digital twin may be utilized to simulate the physical SC by using real transportation, inventory, demand, and capacity data (Ivanov & Dolgui, 2021). Utilizing supplier IT for exploitation streamlines upstream structured activities such as material shipment, inventory management, invoicing, and buying. Businesses may swiftly find alternative materials by using standardized and institutionalized information when the upstream is harmed by disruptions. This enables businesses to address material shortages and bounce back from disruptions quickly, which improves supplier resilience (Gu, Yang, & Huo, 2021).

4.2. Addressing Significant Challenges

The primary obstacles to AI adoption in supply chain management include change management, current technological constraints, human acceptance of these approaches, comprehension and usefulness of these techniques, and people's existing expertise, in addition to the high implementation costs of such solutions. Other obstacles include a lack of openness, problems with security and privacy, a lack of technological principles and abilities, and deficiencies in data, documentation, and the resilience of these solutions (Hangl, Behrens, & Krause, 2022). It is not easy to integrate blockchain into supply chain management. It is necessary to carefully negotiate regulatory constraints, scalability problems, and interoperability issues. Unlocking blockchain's full potential and guaranteeing its smooth incorporation into various supply chain contexts require industry-wide cooperation and standardization initiatives (Oriekhoe et al., 2024). Even though the developing IDT of I4.0 has attracted attention recently, research on the advantages and difficulties of adopting these IDT and their role in fostering an agile supply chain is still in its infancy. Cybersecurity, sophisticated and collaborative robots (CObots), virtual or augmented reality, and other technologies are not well understood (Oliveira-Dias et al., 2022). The fundamental issues with blockchain technology, such as security, usability, and technological immaturity, comprise the technological hurdles. Policies, culture, and managerial commitment are examples of organizational aspects. The supply chain (inter-organizational) perspective encompasses issues such as lack of knowledge, difficulty with collaboration, and information disclosure (Kouhizadeh, Saberi, & Sarkis, 2021). One of the biggest obstacles to the effective adoption of blockchain technology is the business owner's reluctance to try out novel technologies. A significant obstacle to striking a balance between the benefits offered and the possibility of any unexpected repercussions that may follow is regulatory ambiguity (Mathivathanan, Mathiyazhagan, Rana, Khorana, & Dwivedi, 2021). The most significant obstacles are transaction-level uncertainty (B1), usage in the underground economy (B2), management commitment (B5), scalability issues (B3), and privacy threats (B4), in that order of significance (Vafadarnikjoo, Badri Ahmadi, Liou, Botelho, & Chalvatzis, 2023). IoT has a lot of potential uses in supply chains, however there are a lot of implementation issues with the technology. The supply chain faces major obstacles in utilizing IoT to its full potential, including security, privacy, and scalability. IoT is a wireless technology, and numerous sensor nodes provide the foundation for applications. As a result, it raises several possible security issues for users with relation to data storage, data breach during wireless transmission, and storage site security. Certain IoT data are extremely sensitive, may have significant societal repercussions, and are legally protected. RFID technology has the potential to violate civil rights and harm consumer privacy if protections are not put in place (Attaran, 2020). Given that supply chains are intricate Systems of Systems (SoS), cyberattacks may have an impact at the corporate level, particularly if supply chain components depend on data from the Internet of Things. Their effective security is challenged by the integration of infrastructure, technology, and supply chain subnetworks into broader military ecosystems. Implementing Enterprise Architecture (EA) strategies is one possible way to lessen the hazards that system integration within complex supply chain systems poses (Sobb, Turnbull, & Moustafa, 2020).

4.3. Opening Doors to Future Innovations

New technology developments in the SC field prove to be game-changers for many firms. Several writers claim that AI in supply chain management (SCM) would enable businesses to see everything from the raw material to the final customer, giving them more time to make choices and take remedial action (Hangl et al., 2022). Blockchain will become an essential instrument for the optimization and transformation of global supply chains as a result of cross-industry collaboration and the development of decentralized autonomous organizations (DAOs). Businesses who adapt to this changing environment by taking proactive measures to overcome obstacles, valuing teamwork, and utilizing all of block chain's possibilities will not only streamline their supply chain processes but also set themselves up for success as a leader in the coming era of international trade. As the voyage proceeds, block chain serves as a light, pointing the way in the direction of supply chain management's more inventive, transparent, and efficient future (Oriekhoe et al., 2024). SCRM is being revolutionized by AI and ML, which make predictive modeling possible for more precise risk assessment (Coker, Uzougbo, Oguejiofor, & Akagha, 2023). The growing integration of robots, automation, machine learning, and artificial intelligence will define future developments in SCRM and technology. These developments enable businesses to automate decision-making procedures, streamline warehousing and logistics, and proactively detect and address hazards. Organizations who adopt and strategically apply these technologies will be better able to handle the complexity of today's supply chain environment as these trends continue to develop (Odimarha, Ayodeji, & Abaku, 2024). Proactive risk mitigation techniques are made possible by early detection of possible threats. Decision-making processes are improved by increased forecasting and risk assessment accuracy. In order to forecast the possibility of disruptions, AI algorithms may examine past supplier performance, market trends, and geopolitical variables. This capability enables businesses to take proactive risk management measures and make well-informed decisions. One of the main trends in future SCRM is the automation of decision-making processes with AI and ML (Ganesh & Kalpana, 2022). In summary, there is a rising awareness of blockchain's ability to improve efficiency, transparency, and collaboration in supply chains, which characterizes the present stage of its adoption.

These studies offer important insights into the major success factors, difficulties, and directions for future study related to the effective application of blockchain in supply chains.

5. SUCCESSFUL CASE STUDIES

Essentially, a blockchain is an extensive network of IT systems that functions as a digital record of transaction volume spread throughout the network. In the development of e-commerce, this technology serves as a dependable layer. To digitize the food supply chain process and bring transparency to the decentralized food supply ecosystem, Walmart and IBM have been collaborating on a food safety blockchain solution. The success of Walmart's blockchain experiment depended on departmental collaboration. Because blockchain technology aligned with the regulators' mission, they were intrigued by its potential (Sharma & Kumar, 2021). Four major players in the grocery and food industries—Walmart Stores Inc., Nestlé S.A., International Business Machines Corporation, and Dole Food Company Inc.—decided to collaborate to address issues facing the global food supply chain. This decision is detailed in the case study, Applications of Blockchain Technology in Business and Information Systems. Their goal is to accomplish this by tackling the issue of food safety by collaborating with several partners to create a blockchain-based traceability architecture. To explore the blockchain's potential for tracking food product origin, either individually or to obtain industry-wide insights, Walmart has conducted two tests thus far (Eze, Ugwu Chinyere, & Ogenyi Fabian, 2024).

The success of Amazon.com is a result of its significant commitment to automation innovation. The business started developing and implementing a variety of autonomous robots after acquiring Kiva System in 2012, including the Palletizer, Robo-Stow, and several drive unit variations. The acquisition of CANVAS Technology, a technology that would be utilized to develop new drive robots with enhanced vision systems, demonstrated the company's ongoing commitment to innovation. Additionally, Amazon.com collaborates with businesses like SmartPac and CartonWrap to automate the packaging and wrapping of goods for delivery. The Upskilling 2025 effort was started by Amazon.com and offers a variety of programs to help employees learn and advance their abilities in fields including software engineering, IT, machine learning, and cloud computing (Laber, Thamma, & Kirby, 2020). Amazon adopted the concept of F-Warehouses a new type of fulfillment warehouse that solely handles online orders. This allowed for an investigation, which revealed that the corporation operated over 175 of these types of centers, able to fulfill up to 0.5 million units daily (Onal, Zhu, & Das, 2023).

Online grocery delivery is Ocado's business, and it boasts the largest and most automated warehouse in the world. In its automated warehouses in London, Ocado employs a fleet of 3,000 robots that get to work as soon as an order is placed and received. These robots head straight to the containers holding the necessary items and start the fulfilling procedure there. They shift apart by around five millimeters, illustrating how well-organized and fluid the codes and algorithms are, ultimately enabling Ocado to optimize operational efficiency and overall company success. Ocado's satisfaction the corporation can deliver 50% of client orders within 4 hours, compared to 10% if no warehouse automation was implemented, thanks to the 26 centers' architecture, which includes thousands of bots capable of picking 50 products in a matter of minutes (Savushkin, 2024).

With the might of a global corporation and the inventiveness of a start-up, DHL. DHL picks, sorts, and tags items in the warehouse using Industry 4.0 technologies including AR (Augmented Reality) and IoT (Internet of Things). With the usage of Vuzix smart glasses, employees were able to operate in warehouses without using their hands thanks to the benefits of augmented reality (Patil, 2020). Furthermore, DHL Logistics Company investigates a wide range of augmented reality applications in several supply chain activities, including transportation optimization, last-mile delivery, warehouse operations, and improved value-added services (Kamau & Murori, 2024).

6. CONCLUSION AND IMPLICATIONS

The aim is to analyse how in the ecosystem of supply chain management, digital transformation is essential for business sectors to preserve their competitive edge and achieve operational efficiency. In the ecosystem of supply chain management, digital transformation is essential for business sectors to preserve their competitive edge and achieve operational efficiency. Five more efficient uses for the single answer were found by the investigation. Demand forecasting, warehouse automation, transportation and route optimization, supplier selection and management, and predictive maintenance are all made possible by artificial intelligence. Blockchain makes monitoring and transparency possible, improving traceability, reducing counterfeiting, promoting ethical and sustainable sourcing, and facilitating intelligent payments. Better communication, cost monitoring, inventory control, tracking key performance indicators, and optimized visualization are all guaranteed by business intelligence. Demand forecasting, route optimization, inventory control, risk assessment, and supplier management are all made easier by data science. Tracking shipments and deliveries, inventory management, warehouse capacity monitoring, storage condition monitoring, routine optimization, and automation are all made possible by IoT. RFID works well for supply chain visibility, retail management, freight transportation, warehouse management, and inventory management. Automation and robotics are used in collaborative robots, automated guided vehicles, automated storage and retrieval systems, warehouse management, control, and monitoring.

Leaders in the industry and policymakers are urged to take these suggestions into account to fully utilize blockchain technology and improve SCM processes' resilience, sustainability, and efficiency. SCM's future is in utilizing these cutting-edge technologies, and blockchain is at the vanguard of this revolutionary voyage. For SCRM to be effective, industry stakeholders must work together. Organizations may communicate pertinent information about industry trends, best practices, and possible hazards by forming partnerships for data sharing. By establishing cooperative platforms, partners and rivals may both add to a shared knowledge of the supply chain environment and enable better-informed risk management tactics. The idea behind blockchain technology is to eliminate the supply chain's conventional division. Blockchain offers a new value creation based on automotive supply chain theories, which is a basis for additional empirical research, from the perspectives of extensibility, degrees of freedom, redesign of automotive supply chain visibility, operational efficiency, and new business model. Managers and staff members need to be more open-minded for digital technology to be used successfully. The process of digital transformation is mostly driven by the executives. They must embrace technology and give it top attention. They must critically examine their company and its goals; they must also establish business cases, solutions, strategies, and roadmaps.

Funding: This study received no specific financial support.
Institutional Review Board Statement: Not applicable.
Transparency: The authors declare that the manuscript is honest, truthful and transparent, that no important aspects of the study have been omitted and that all deviations from the planned study have been made clear. This study followed all rules of writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

REFERENCES

Abeyratne, S. A., & Monfared, R. P. (2016). Blockchain ready manufacturing supply chain using distributed ledger. *International Journal of Research in Engineering and Technology, 5*(9), 1-10. https://doi.org/10.15623/ijret.2016.0509001

Accenture. (2020a). *Leveraging BI for cost reduction in global supply chains.* Retrieved from https://www.accenture.com. [Accessed 3 October 2024]

Accenture. (2020b). *RFID in warehouse management: Reducing labor costs and improving efficiency.* Retrieved from https://www.accenture.com. [Accessed 3 October 2024]

Accenture. (2021). *The role of IoT in optimizing supply chain inventory management.* Retrieved from https://www.accenture.com. [Accessed 3 October 2024]

Akbari, M., Nguyen, T. H., & Le, D. T. (2024). Digital technologies and the transformation of supply chains in Vietnam: Embracing Industry 4.0. *Journal of Supply Chain Innovation, 18*(3), 102-118. https://doi.org/10.1016/j.josci.2024.03.002

Al-Mobaideen, H. (2014). The role of business intelligence in transforming business decision-making processes. *International Journal of Business Intelligence Research, 5*(2), 1-15. https://doi.org/10.4018/IJBIR.2014070101

AlMulhim, A. (2021). The role of smart technologies in bridging digital transformation and firm performance. *Journal of Digital Transformation and Business Performance, 10*(3), 134-148. https://doi.org/10.1016/j.jdtbp.2021.07.003

Amazon Robotics. (2021). *Kiva systems and the revolution of warehouse automation.* Retrieved from https://www.amazon.com/. [Accessed 3 October 2024]

Anitha, P., & Patil, M. M. (2018). A review on data analytics for supply chain management: A case study. *International Journal of Information Engineering and Electronic Business, 14*(5), 30.

Arenkov, D., Ivanov, D., & Pavlov, A. (2019). Industry 4.0 technologies and their impact on business growth and supply chains: Exploring emerging value-generating methods. *International Journal of Advanced Manufacturing Technology, 46*(5), 1029-1045. https://doi.org/10.1007/s00170-019-03785-w

Attaran, M. (2020). Digital technology enablers and their implications for supply chain management. *Supply Chain Forum: An International Journal, 21*(3), 158-172. https://doi.org/10.1080/16258312.2020.1751568

Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of things: A survey. *Computer Networks, 54*(15), 2787-2805. https://doi.org/10.1016/j.comnet.2010.05.010

Baryannis, G., Validi, S., & Nivolianitou, Z. (2019). Predicting supply chain risks using artificial intelligence: A review. *Computers & Industrial Engineering, 127*, 563-574. https://doi.org/10.1016/j.cie.2018.11.012

Bayramova, A., Edwards, D. J., & Roberts, C. (2021). The role of blockchain technology in augmenting supply chain resilience to cybercrime. *Buildings, 11*(7), 283. https://doi.org/10.3390/buildings11070283

Bechtsis, D., Tsolakis, N., Vlachos, D., & Iakovou, E. (2017). Sustainable supply chain management in the digitalisation era: The impact of Automated Guided Vehicles. *Journal of Cleaner Production, 142*, 3970-3984. https://doi.org/10.1016/j.jclepro.2016.10.057

Bigliardi, B., Filippelli, S., Petroni, A., & Tagliente, L. (2022). The digitalization of supply chain: A review. *Procedia Computer Science, 200*, 1806-1815.

Birkel, H., & Müller, J. M. (2021). Potentials of industry 4.0 for supply chain management within the triple bottom line of sustainability–A systematic literature review. *Journal of Cleaner Production, 289*, 125612. https://doi.org/10.1016/j.jclepro.2020.125612

BMW. (2020). *Leveraging IoT for real-time supply chain visibility.* Retrieved from https://www.bmw.com. [Accessed 3 October 2024]

Boston Consulting Group. (2020). *The future of collaborative robots in supply chains.* Retrieved from https://www.bcg.com. [Accessed 3 October 2024]

Capgemini. (2021). *IoT and automation in supply chain optimization.* Retrieved from https://www.capgemini.com. [Accessed 3 October 2024]

Capgemini Research Institute. (2020). *AI in logistics: Driving route optimization and efficiency.* Retrieved from https://www.capgemini.com/research. [Accessed 3 October 2024]

Carrefour. (2020). *RFID in inventory management: Automating stock counts for greater accuracy.* Retrieved from https://www.carrefour.com. [Accessed 3 October 2024]

Caserio, C., & Trucco, S. (2018). Enterprise resource planning and business intelligence systems for information quality. In (pp. 21). Cham, Switzerland: Springer.

Chakraborty, A., Choudhury, P. K., & Tiwari, M. K. (2020). Predicting fashion trends with machine learning: A logistic regression approach. *Journal of Fashion Technology & Textile Engineering, 8*(2), 130-139. https://doi.org/10.4172/2329-9568.1000191

Chatterjee, S., Chaudhuri, R., & Vrontis, D. (2024). Examining the impact of adoption of emerging technology and supply chain resilience on firm performance: Moderating role of absorptive capacity and leadership support. *IEEE Transactions on Engineering Management, 7*, 10373-10386. https://doi.org/10.1109/TEM.2021.3134188

Choi, T. Y., Rogers, D. S., & Vakil, B. (2018). RFID in supply chain management: A review and future directions. *International Journal of Operations & Production Management, 38*(2), 409-436. https://doi.org/10.1108/IJOPM-11-2016-0502

Coca-Cola. (2020). *Blockchain and sustainability in the circular economy.* Retrieved from https://www.coca-cola.com

Coker, J. O., Uzougbo, N. S., Oguejiofor, B. B., & Akagha, O. V. (2023). The role of legal practitioners in mitigating corporate risks in Nigeria: A comprehensive review of existing literature on the strategies and approaches adopted by legal practitioners in Nigeria to mitigate corporate risks. *Finance & Accounting Research Journal*, *5*(10), 309-332.

Crosby, M., Pattanayak, P., Verma, S., & Kalyanaraman, V. (2016). Blockchain technology: Beyond bitcoin. *Applied Innovation Review*, *2*(6), 6-10.

Davenport, T. H., & Harris, J. G. (2017). *Competing on analytics: The new science of winning*. Boston, MA: Harvard Business Press.

De Beers. (2020). *Tracr: Transforming the diamond industry with blockchain*. Retrieved from https://www.debeersgroup.com. [Accessed 3 October 2024]

Decathlon. (2021). *RFID-enabled self-checkout: Enhancing customer experience in retail*. Retrieved from https://www.decathlon.com. [Accessed 3 October 2024]

Deloitte. (2020a). *Enhancing operational intelligence in supply chain management through AI/ML. Supply Chain Management Review*. Retrieved from https://www.scmr.com. [Accessed 3 October 2024]

Deloitte. (2020b). *Enhancing supply chain transparency with blockchain*. Retrieved from https://www.deloitte.com. [Accessed 3 October 2024]

Deloitte. (2021a). *Automated storage and retrieval systems: Optimizing space and increasing throughput*. Retrieved from https://www.deloitte.com. [Accessed 3 October 2024]

Deloitte. (2021b). *The impact of IoT on shipment tracking and delivery performance*. Retrieved from https://www2.deloitte.com. [Accessed 3 October 2024]

Dhaliwal, A. (2020). The rise of automation and robotics in warehouse management. In: Transforming Management Using Artificial Intelligence Techniques. In (pp. 63-72). Boca Raton, FL: CRC Press.

DHL. (2022). *Using RFID to improve freight transportation and asset utilization*. Retrieved from https://www.dhl.com. [Accessed 3 October 2024]

Duan, Y., Edwards, J. S., & Dwivedi, Y. K. (2019). Artificial intelligence for decision making in the era of big data: A review. *Journal of Decision Systems*, *28*(2), 83-98. https://doi.org/10.1080/12460125.2019.1613245

Dubey, R., Gunasekaran, A., & Childe, S. J. (2020). Artificial intelligence in supply chain management: Applications, opportunities, and challenges. *International Journal of Production Research*, *58*(15), 4481-4499. https://doi.org/10.1080/00207543.2019.1648234

Eze, V. H. U., Ugwu Chinyere, N., & Ogenyi Fabian, C. (2024). Blockchain-enabled supply chain traceability in food safety. *Research Output Journal of Biological and Applied Science*, 46-51.

Fanti, M. P., Gabbrielli, R., & Pappalardo, G. (2017). RFID-enabled supply chain management: Optimizing the inventory and logistics. *Computers & Industrial Engineering*, *113*, 612-624. https://doi.org/10.1016/j.cie.2017.09.010

Fawcett, S. E., Magnan, G. M., & McCarter, M. W. (2008). A three-stage implementation model for supply chain collaboration. *Journal of Business Logistics*, *29*(1), 93-112. https://doi.org/10.1002/j.2158-1592.2008.tb00070.x

Feizabadi, J. (2022). Machine learning demand forecasting and supply chain performance. *International Journal of Logistics Research and Applications*, *25*(2), 119-142.

Ford Motor Company. (2021). *Ford blockchain initiative for ethical sourcing*. Retrieved from https://www.ford.com. [Accessed 3 October 2024]

Galati, F., & Bigliardi, B. (2019). Industry 4.0: Emerging themes and future research avenues using a text mining approach. *Computers in Industry*, *109*, 100-113.

Ganesan, S., Gupta, H., & Kumar, R. (2017). Impact of automation on efficiency and safety in warehousing: A review. *Robotics and Computer-Integrated Manufacturing*, *47*, 145-156. https://doi.org/10.1016/j.rcim.2017.03.006

Ganesh, A. D., & Kalpana, P. (2022). Future of artificial intelligence and its influence on supply chain risk management–A systematic review. *Computers & Industrial Engineering*, *169*, 108206.

Gao, X., Li, Z., & Wang, Y. (2022). Exploring the domains of digitization, digitalization, and digital transformation: A systematic review. *Journal of Digital Innovation*, *12*(4), 245-263. https://doi.org/10.1016/j.jdi.2022.03.001

Gartner. (2020a). *IoT-enabled storage condition monitoring: Ensuring product quality and compliance*. Retrieved from https://www.gartner.com. [Accessed 3 October 2024]

Gartner. (2020b). *Predictive analytics in inventory management: Reducing waste and improving efficiency*. Retrieved from https://www.gartner.com. [Accessed 3 October 2024]

Gartner. (2021a). *AI-powered control systems in robotics: Enhancing efficiency and reducing downtime*. Retrieved from https://www.gartner.com. [Accessed 3 October 2024]

Gartner. (2021b). *The role of BI in tracking supply chain KPIs*. Retrieved from https://www.gartner.com. [Accessed 3 October 2024]

Gartner. (2022a). *AI in supply chain management and supplier risk assessment*. Retrieved from https://www.gartner.com/en/supply-chain. [Accessed 3 October 2024]

Gartner. (2022b). *The role of blockchain in sustainable supply chains*. Retrieved from https://www.gartner.com. [Accessed 3 October 2024]

Gartner. (2022c). *The role of RFID in retail management: Reducing shrinkage and improving sales*. Retrieved from https://www.gartner.com. [Accessed 3 October 2024]

GE Healthcare. (2021). *Using AI and automation to improve supply chain performance*. Retrieved from https://www.gehealthcare.com

Gu, M., Yang, L., & Huo, B. (2021). The impact of information technology usage on supply chain resilience and performance: An ambidexterous view. *International Journal of Production Economics*, *232*, 107956. https://doi.org/10.1016/j.ijpe.2020.107956

Guru, R., Khan, M. A., & Deshmukh, S. G. (2018). The impact of automated guided vehicles (AGVs) on material handling costs and operational efficiency. *International Journal of Advanced Manufacturing Technology*, *96*(5-8), 2013-2026. https://doi.org/10.1007/s00170-018-1992-4

Hangl, J., Behrens, V. J., & Krause, S. (2022). Barriers, drivers, and social considerations for AI adoption in supply chain management: A tertiary study. *Logistics*, *6*(3), 63. https://doi.org/10.3390/logistics6030063

Hartley, J. L., & Sawaya, W. J. (2019). Tortoise, not the hare: Digital transformation of supply chain business processes. *Business Horizons*, *62*(6), 707-715.

Harvard Business Review. (2020). *How PepsiCo uses data science to predict demand*. Retrieved from https://www.hbr.org

Helo, P., & Hao, Y. (2022). The impact of artificial intelligence on business and supply chain innovation: A review. *Journal of Supply Chain Management*, *58*(1), 75-90. https://doi.org/10.1111/jscm.12251

Hribar, M., Pucihar, A., & Rajh, E. (2019). The role of data science in supply chain management: Insights from data analytics for forecasting and market prediction. *International Journal of Production Economics*, *216*, 100-112 https://doi.org/10.1016/j.ijpe.2019.04.007

IBM. (2020). *Leveraging data science for hazard assessment in global supply chains*. Retrieved from https://www.ibm.com

IBM. (2021). *Predictive maintenance powered by AI: Minimizing downtime and maintenance costs*. Retrieved from https://www.ibm.com

Intel. (2021). *Using machine learning for supplier administration and selection*. Retrieved from https://www.intel.com

Islam, S., & Amin, S. H. (2020). Prediction of probable backorder scenarios in the supply chain using Distributed Random Forest and Gradient Boosting Machine learning techniques. *Journal of Big Data*, *7*(1), 65. https://doi.org/10.1007/s00170-019-03942-9

Ivanov, D., & Dolgui, A. (2021). A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. *Production Planning & Control*, *32*(9), 775-788. https://doi.org/10.1080/09537287.2020.1768450

Jafari, T., Zarei, A., Azar, A., & Moghaddam, A. (2023). The impact of business intelligence on supply chain performance with emphasis on integration and agility–a mixed research approach. *International Journal of Productivity and Performance Management*, *72*(5), 1445-1478. https://doi.org/10.1108/ijppm-09-2021-0511

Jourdan, Z., Rainer, E. M., & Klein, H. K. (2008). Business intelligence: A case for the 'architecture of decisions'. *Communications of the Association for Information Systems*, *23*(1), 10-23. https://doi.org/10.17705/1CAIS.02312

Kamau, C. G., & Murori, C. K. (2024). Characteristics of creative accounting: A multifaceted literature analysis. *World Journal of Advanced Research and Reviews*, *23*(1), 2035-2043. https://doi.org/10.30574/wjarr.2024.23.1.2177

Kamble, S. S., Gunasekaran, A., & Sharma, R. (2019). Modeling the green supply chain management practices in the context of RFID technology: A structural equation approach. *International Journal of Production Economics, 211*, 1-12. https://doi.org/10.1016/j.ijpe.2019.01.008

Kamley, N., Prakash, A., & Karan, K. (2016). Business data analytics and data science for supply chain management: A competitive edge approach. *International Journal of Logistics Research and Applications, 19*(5), 435-446. https://doi.org/10.1080/13675567.2016.1183159

Karmaker, C. L., Ahmed, T., Ahmed, S., Ali, S. M., Moktadir, M. A., & Kabir, G. (2021). Improving supply chain sustainability in the context of COVID-19 pandemic in an emerging economy: Exploring drivers using an integrated model. *Sustainable Production and Consumption, 26*, 411-427.

Karpova, N. P. (2022). Modern warehouse management systems. In Digital Technologies in the New Socio-Economic Reality. In (pp. 261-267). Cham, Switzerland: Springer International Publishing.

Kazancoglu, I., Ozbiltekin-Pala, M., Mangla, S. K., Kumar, A., & Kazancoglu, Y. (2023). Using emerging technologies to improve the sustainability and resilience of supply chains in a fuzzy environment in the context of COVID-19. *Annals of Operations Research, 322*(1), 217-240. https://doi.org/10.1007/s10479-022-04775-4

Keurulainen, S. (2024). Big data analytics as a driver in supply chain risk management process.

Khakpour, A., Colomo-Palacios, R., & Martini, A. (2021). Visual analytics for decision support: A supply chain perspective. *IEEE Access, 9*, 81326-81344.

Kirtane, A., Tiwari, A., Lalwani, Y., Sood, J., Pasha, A., & Hisham, M. (2024). *Supply chain visualization and optimization using machine learning*. Paper presented at the 2024 IEEE 9th International Conference for Convergence in Technology (I2CT) (pp. 1-7). IEEE.

Kotu, V., & Deshpande, B. (2019). *Data science: Concepts and practice*. San Francisco, CA: Morgan Kaufmann.

Kouhizadeh, M., Saberi, S., & Sarkis, J. (2021). Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers. *International Journal of Production Economics, 231*, 107831. https://doi.org/10.1016/j.ijpe.2020.107831

Krueger, A., Sutherland, J., & Rohn, J. (2016). Advanced robotics in warehouse and manufacturing operations. *Journal of Manufacturing Technology Management, 27*(7), 930-948. https://doi.org/10.1108/JMTM-04-2015-0075

Kurpjuweit, S., Neumann, S., & Müller, J. (2021). Blockchain for supply chain resilience: Challenges and opportunities in the post-pandemic era. *Supply Chain Management Review, 17*(5), 100-110. https://doi.org/10.1108/SCMR-06-2021-0145

Laber, J., Thamma, R., & Kirby, E. D. (2020). The impact of warehouse automation in amazon's success. *International Journal of Innovations in Science & Technology, 7*, 63-70.

Langlois, A., & Chauvel, B. (2017). The impact of supply chain management on business intelligence. *Journal of Intelligence Studies in Business, 7*(2), 51-61.

Lerman, G., Smith, J., & Zhang, Y. (2024). The impact of digital transformation on supply chain management: Supporting firms' social and economic performance in emerging markets. *Journal of Supply Chain and Digital Transformation, 15*(2), 45-60. https://doi.org/10.1016/j.scdt.2024.01.004

Li, X., Zhang, X., & Liu, Y. (2022). The impact of COVID-19 on supply chain resilience: A global perspective. *International Journal of Operations & Production Management, 42*(1), 15-30. https://doi.org/10.1108/IJOPM-04-2021-0412

LVMH. (2020). *Aura: Blockchain platform for luxury goods*. Retrieved from https://www.lvmh.com

Maersk. (2020). *Blockchain and smart payments in global shipping*. Retrieved from https://www.maersk.com

Mathivathanan, D., Mathiyazhagan, K., Rana, N. P., Khorana, S., & Dwivedi, Y. K. (2021). Barriers to the adoption of blockchain technology in business supply chains: A total interpretive structural modelling (TISM) approach. *International Journal of Production Research, 59*(11), 3338-3359. https://doi.org/10.1080/00207543.2020.1868597

McKinsey & Company. (2021). *The impact of AI on demand forecasting: Unlocking cost savings and reducing errors. McKinsey & Company.* Retrieved from https://www.mckinsey.com/

McKinsey & Company. (2021a). *Succeeding in the AI supply-chain revolution*. Retrieved from https://www.mckinsey.com/business-functions/operations/our-insights/succeeding-in-the-ai-supply-chain-revolution

McKinsey & Company. (2021b). *Blockchain and traceability in the pharmaceutical industry*. Retrieved from https://www.mckinsey.com

McKinsey & Company. (2021c). *Data science and inventory optimization: The future of supply chains*. Retrieved from https://www.mckinsey.com

McKinsey & Company. (2021d). *Enhancing supply chain visibility with RFID technology*. Retrieved from https://www.mckinsey.com

McKinsey & Company. (2021e). *The role of robotics in modern warehouses: Improving efficiency and reducing costs*. Retrieved from https://www.mckinsey.com

McKinsey & Company. (2022). *The future of warehouse management: How IoT is revolutionizing storage solutions*. Retrieved from https://www.mckinsey.com

Meticulous Research. (2024). *AI in warehouse automation: The future of supply chains*. Retrieved from https://www.meticulousresearch.com

Miorandi, D., Sicari, S., De Pellegrini, F., & Chlamtac, I. (2012). Internet of things: Vision, applications and research challenges. *Ad Hoc Networks, 10*(7), 1497-1516. https://doi.org/10.1016/j.adhoc.2012.02.016

Moglia, M., Alvarez, P., & Marquez, A. (2021). Energy efficiency and sustainability in automated supply chains: Reducing emissions with robotics. *International Journal of Logistics Research and Applications, 24*(4), 337-352. https://doi.org/10.1080/13675567.2021.1941243

Mohan Banur, O., Patle, B., & Pawar, S. (2024). Integration of robotics and automation in supply chain: A comprehensive review. *Robotic Systems and Applications, 4*(1), 1-19. https://doi.org/10.1016/j.ijiem.2024.02.004

Musa, S., & Dabo, M. (2016). Radio frequency identification (RFID) applications in supply chain management: A comprehensive review. *Journal of Manufacturing Systems, 40*, 10-18. https://doi.org/10.1016/j.jmsy.2016.06.001

Nguyen, T., Phan, D. A., & Le, T. (2021). AI-based forecasting techniques for supply chain optimization. *Journal of Artificial Intelligence in Business, 12*(4), 100-115. https://doi.org/10.1016/j.jaib.2021.03.004

Odimarha, A. C., Ayodeji, S. A., & Abaku, E. A. (2024). The role of technology in supply chain risk management: Innovations and challenges in logistics. *Magna Scientia Advanced Research and Reviews, 10*(2), 138-145. https://doi.org/10.30574/msarr.2024.10.2.0052

Okabe, K., & Otsuka, Y. (2021). Machine breakdown analysis using artificial intelligence and predictive maintenance. *Journal of Manufacturing Science and Engineering, 143*(2), 025004. https://doi.org/10.1115/1.4050492

Oliveira-Dias, D., Maqueira-Marín, J. M., & Moyano-Fuentes, J. (2022). The link between information and digital technologies of industry 4.0 and agile supply chain: Mapping current research and establishing new research avenues. *Computers & Industrial Engineering, 167*, 108000. https://doi.org/10.1016/j.cie.2022.108000

Onal, S., Zhu, W., & Das, S. (2023). Order picking heuristics for online order fulfillment warehouses with explosive storage. *International Journal of Production Economics, 256*, 108747. https://doi.org/10.1016/j.ijpe.2022.108747

Oriekhoe, O. I., Oyeyemi, O. P., Bello, B. G., Omotoye, G. B., Daraojimba, A. I., & Adefemi, A. (2024). Blockchain in supply chain management: A review of efficiency, transparency, and innovation. *International Journal of Science and Research Archive, 11*(1), 173-181. https://doi.org/10.30574/ijsra.2024.11.1.0028

Patil, D. A. (2020). The study of industry 4.0 and its impact on supply chain management. *International Research Journal of Engineering and Technology, 7*, 2020-2038.

Pfizer. (2021a). *RFID and temperature monitoring in vaccine transportation*. Retrieved from https://www.pfizer.com

Pfizer. (2021b). *Using IoT to monitor storage conditions for vaccine distribution*. Retrieved from https://www.pfizer.com

PwC. (2021). *Blockchain and smart contracts in supply chain payments*. Retrieved from https://www.pwc.com

Ragazou, E., Apostolou, D., & Karampinis, I. (2023). Business intelligence in the digital age: Tools, techniques, and applications. *Journal of Business Analytics, 12*(2), 122-137.

Rezaei, J., Ortt, R., & Roodhooft, F. (2017). Internet of Things in supply chain decision making. *Computers in Industry, 91*, 97-109. https://doi.org/10.1016/j.compind.2017.08.005

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and the supply chain: A systematic review of the literature. *International Journal of Production Research, 57*(7), 2117-2135. https://doi.org/10.1080/00207543.2018.1533261

Sabherwal, R., & Becerra-Fernandez, I. (2013). *Business intelligence: Practices, technologies, and management*. Hoboken, NJ: Wiley.

Sahoo, S., Kumar, A., & Upadhyay, A. (2023). How do green knowledge management and green technology innovation impact corporate environmental performance? Understanding the role of green knowledge acquisition. *Business Strategy and the Environment, 32*(1), 551-569.

Sarac, A., Abolhasani, M., & Syntetos, A. A. (2010). A review of RFID applications in supply chain management. *International Journal of Production Economics, 128*(1), 61-73. https://doi.org/10.1016/j.ijpe.2010.07.020

Sarkis, J. (2020). Supply chain management and COVID-19: The implications of the pandemic on supply chain resilience. *Journal of Supply Chain Management, 56*(4), 78-91. https://doi.org/10.1111/jscm.12299

Savushkin, N. (2024). Warehouse automation in logistics: Case study of Amazon and Ocado.

Schmidt, C. G., & Wagner, S. M. (2019). Blockchain and supply chain relations: A transaction cost theory perspective. *Journal of Purchasing and Supply Management, 25*(4), 100552.

Seddon, P. B., Constantinides, P., & Tzuo, H. (2017). The impact of business intelligence and analytics on business performance: A conceptual framework. *Journal of Information Technology, 32*(1), 24-45. https://doi.org/10.1057/s41265-016-0028-2

Sharma, A., Singh, S., & Gupta, S. (2022). Advancements in artificial intelligence: Applications in computer vision, speech recognition, and automation. *Journal of Artificial Intelligence and Automation, 15*(3), 210-225. https://doi.org/10.1016/j.jaia.2022.01.006

Sharma, M., & Kumar, P. (2021). Adoption of blockchain technology: A case study of Walmart. In R. Bansal, P. Malyadri, A. Singh, & A. Pervez (Eds.), Advances in Marketing, Customer Relationship Management, and E-Services. In (pp. 210–225): IGI Global. https://doi.org/10.4018/978-1-7998-8081-3.ch013.

Sherman, R. (2014). *Business intelligence guidebook: From data integration to analytics*: Newnes.

Shollo, A., & Kautz, K. (2010). Business intelligence and its impact on decision making. *Information Systems Management, 27*(4), 297-308. https://doi.org/10.1080/10580530.2010.519139

Siemens. (2021a). *AI-driven control systems in manufacturing: Optimizing robotic performance*. Retrieved from https://www.siemens.com/global/en/products/automation/topic-areas/artificial-intelligence-in-industry.html

Siemens. (2021b). *RFID-enabled warehouse automation: Reducing retrieval times by 30%*. Retrieved from https://www.siemens.com

Sobb, T., Turnbull, B., & Moustafa, N. (2020). Supply chain 4.0: A survey of cyber security challenges, solutions and future directions. *Electronics, 9*(11), 1864. https://doi.org/10.3390/electronics9111864

Stefanovic, N. (2014). Proactive supply chain performance management with predictive analytics. *The Scientific World Journal, 2014*(1), 528917.

Stroumpoulis, K., & Kopanaki, M. (2022). The adoption of technologies and the relationship between sustainable supply chain management and digital transformation: A conceptual framework. *International Journal of Sustainable Supply Chain Management, 9*(4), 255-273. https://doi.org/10.1016/j.ijsscm.2022.06.005

Tagarakis, A., Andriani, A., & Sideris, A. (2021). Improving food supply chains through the Internet of Things: Applications and challenges. *Food Control, 123*, 107757. https://doi.org/10.1016/j.foodcont.2020.107757

Thirumalai, S. (2014). Supplier selection and procurement strategies in the context of global supply chains. *Journal of Supply Chain Management, 50*(3), 23-40. https://doi.org/10.1111/jscm.12044

Tu, Y., Liu, C., & Li, L. (2018). IoT-based supply chain management for transportation systems. *International Journal of Logistics Management, 29*(2), 611-625. https://doi.org/10.1108/IJLM-11-2017-0315

Unilever. (2020). *Leveraging RFID for supplier management and supply chain resilience*. Retrieved from https://www.unilever.com

Unilever. (2021). *Unilever blockchain initiative for sustainable palm oil*. Retrieved from https://www.unilever.com

Universal Robots. (2021). *Cobots for small and medium-sized enterprises (SMEs): Flexibility and scalability in production. Universal Robots*. Retrieved from https://www.universal-robots.com

Vafadarnikjoo, A., Badri Ahmadi, H., Liou, J. J., Botelho, T., & Chalvatzis, K. (2023). Analyzing blockchain adoption barriers in manufacturing supply chains by the neutrosophic analytic hierarchy process. *Annals of Operations Research, 327*(1), 129-156. https://doi.org/10.1007/s10479-021-04048-6

Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J. Q., Fabian, N., & Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research, 122*, 889-901.

Waller, M. A., & Fawcett, S. E. (2013). Data science, predictive analytics, and big data: A revolution that will transform supply chain design and management. In (Vol. 34, pp. 77-84): Wiley Online Library.

Wieder, P., & Ossimitz, M. (2015). Business intelligence as a process: A dynamic capability perspective. *Journal of Decision Systems, 24*(3), 137-156. https://doi.org/10.1080/12460125.2015.1038404

World Economic Forum. (2021). *The impact of counterfeiting on the global economy and how blockchain can help. World Economic Forum*. Retrieved from https://www.weforum.org/

Wortmann, F., & Flüchter, K. (2015). *Internet of things: Technology, business, and applications*. Wiesbaden, Germany: Springer Vieweg.

Wu, Z., Ma, Y., & Zhao, Z. (2021). The Internet of Things: Framework, research challenges, and opportunities. *Journal of Industrial Information Integration, 19*, 100-118. https://doi.org/10.1016/j.jii.2020.100118

Zara. (2021). *How IoT and automation are transforming fashion supply chains*. Retrieved from https://www.zara.com

Zebra Technologies. (2021). *RFID in inventory management: Improving visibility and reducing shrinkage*. Retrieved from https://www.zebra.com